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ABSTRACT

The contents of this collaborative report are as follows: Chapter I--Terms of Reference. Chapter II--Historical Summary of Non-Research. Chapter III--Studies of Urban Infrastructure Elements: (A) Domestic Water Supply; (B) Removal and Treatment Solid and Liquid Wastes; (C) Domestic Power Supply; (D) Urban Transportation; (E) Urban Land. Chapter IV--Summary of Conclusions and Research Needs. Chapter V--The Next Step. [For related documents in this series, see UD 013 731-UD 013 744 for surveys of specific countries. For special studies analyzing urbanization in the Third World, see UD 013 745 and 013 747-748.] (Author/SB)

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An International
Urbanization Survey Report
to the Ford Foundation

Infrastructure Problems of the Cities of Developing Countries

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This working paper was prepared as supportive material for an International Survey of Urbanization in the developing countries, which was organized by the Ford Foundation late in 1970 and was completed late in 1972. The purpose of the Survey was to provide findings and recommendations to guide the Foundation in making informed judgments on its future participation in programs related to the urban condition in the less-developed countries.

The Survey was directed neither to perform nor to commission original research. Its work was to be reportorial, analytic, and indicative of program choices. To serve these objectives, the Survey was essentially a field operation in which the staff travelled widely in the countries where the Foundation maintains field offices and drew not only upon its own observations but upon the experience of Foundation personnel assigned to the developing countries. The staff's own field notes on phases of urbanization in specific countries were expanded into working papers both to record observations and to clarify the deductive processes and the analyses of data which were to form a demonstrable basis for the Survey's conclusions. Additional working papers were provided by Foundation personnel with a depth of field knowledge, and by consultants expert either in specific countries or in topics of special interest.

The Survey working papers and special studies were originally intended only for internal use. It became evident, however, that the body of material had values which argued for wider exposure. Accordingly, the Foundation is publishing the papers for those with special country or topical interests and for those interested in the material as a whole.

The working papers carry disclaimers appropriate to the circumstances of their preparation and to the limitations of their original purpose. The reader should not expect to find in them either the product of original research or a comprehensive treatment of the processes of urbanization in the particular country. Rather, they are occasional papers whose unity derives from their use as exemplary and illustrative material for the Survey.

But unity of form and substance is not the measure of their value. Each report and special study is an essay on some aspect of urbanization in the developing countries. In most instances, they are what a good essay should be—unmistakably personalized and therefore reflective of the insights and the convictions of informed authors.

The International Urbanization Survey

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ED 079465

Infrastructure Problems of the Cities of Developing Countries

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International Urbanization Survey

The Ford Foundation

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INTRODUCTION

This review is a collaborative effort, not merely a collection of individual reports.

The overall attitude and approach to the problems of urban infrastructure in LDC's was discussed and debated at length amongst the contributors. Although differences in emphasis and detail remain, agreement on the general thesis was unanimous, as were the lamentations over the lack of adequate time!

A.	Domestic Water Supply	Judith Rees
B.	Removal of Solid and Liquid Wastes	John C. Wylie
C.	Domestic Power Supply	Michael Foot, Michael Roberts
D.	Urban Transportation	Michael Tyler

Otto H. Koenigsberger and Beverly Bernstein contributed overall direction and coordination as well as the section on 'Urban Land'.

July, 1971

CHAPTER I TERMS OF REFERENCE

1. There is a need to design urban systems which respond both to the resources available in various countries and to the different time scales of potential change in these resources.*
that is:

Urban infrastructure systems need to be designed specifically to fit the income levels of different countries, taking account of the ways in which incomes are likely to change over time.

The technological alternatives used in advanced countries will continue to evolve to fit the income levels of advanced countries and will not necessarily suit the lesser developed countries.

1.2. Leading on from the general statements above, the Ford Foundation requested '...a Study and Report on the Feasibility of Developing a Specialized Technology for the Installation and Operation of

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* David E. Bell, "Ekistics"; Vol. 30, No. 179, Oct. 1970; p. 321-322.

Urban Infrastructure in Developing Countries.'*

The main question posed to this study is:

What level of urban services and what degree of quality in its urban environment might the country be capable of supporting on the basis of its present or projected per capita income?

1.3. The specific services to be included are domestic water supply; removal of solid and liquid wastes; domestic power supply; urban transportation; and urban land. The terms of reference suggest:

1.3.1. that the feasibility of low-cost infrastructure is by no means assured;

1.3.2. that particular attention should be given to short-range systems, either disposable or incremental;

1.3.3. that accepted standards and methodologies be challenged when warranted.

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* J. Robin, Statement on Terms of Reverence No. V; January, 1971.

1.4. As a starting point certain realities were accepted.

1.4.1. Although the cities of the LDC's are growing fast, the urban governments have no control over the rate and little control over the location of urban growth.

1.4.2. There is a limited amount of capital available for investment in urban infrastructure and even if such investment is profitable, the competition for existing capital is too great to favour urban infrastucture schemes.

1.4.3. Managerial, design or planning skills are in short supply, yet they are the major factors which could be ameliorated by international technical assistance.

1.4.4. Long-term, low-interest loans for public utilities in developing countries are another possibility but are heavily dependent upon world-wide priority decisions.

1.5. The working method was agreed to be:

1.5.1. Compilation of an inventory of technology, research and programmes of urban infrastructure presently employed.

1.5.2. A feasibility study of various solutions (particularly those which are labour-intensive, impermanent, incremental, self-help).

1.5.3. Suggestions and recommendations for further research and contribution of international assistance, particularly by the Ford Foundation.

CHAPTER II HISTORICAL SUMMARY OF NON-RESEARCH

1. INTRODUCTION

If one had to date the beginning of interest in what is here called urban infrastructure, one could start with the viaducts of Nineveh. But to tie this historical chapter to relatively more current urban situations, a good starting point is the 19th century and the cholera epidemics in England. These epidemics prompted the City doctors to pressure business and municipal interests to enact more stringent public sanitation laws.

These early movements were a crusade, and the success of this crusade willed to doctors a strong position in all aspects of city management related to sanitation and hygiene. The standards evolved by the medical profession are absolute and aim to 'perfect' standardized sanitary conditions, regardless of economic, climatic or social factors. The research initiated and carried out by the medical profession strives for this perfection solely in consideration of health aspects.

1.2. Doctors were well served by the engineers who built to the briefs given to them. The engineers, trained to meet with efficiency a client's requirements also turned their skills toward a perfect universal solution. The engineers' frame of mind was reinforced by the attitudes of the public accountant. This official, whatever his actual title, was keen to procure the best value for the taxpayers' money. It should be built to last, well-done and politically safe. This medical/mortar/money combine resulted in unadventurous solutions, suitable only to affluent countries with stable economic growth rates.

1.3. Somewhere along the way to the second half of the twentieth century, economists began to exert some influence in public affairs. But the sub-structure of cities seemed to have escaped great tomes of theory and very little interest is evident of a concern with urban infrastructure as a whole. The lure of national--and now regional--economics left cities to other social scientists, notably the sociologists.

1.4. Sociologists have done an enormous amount of work in cities. Interesting books, and varying me-

thods of sociology investigation have highlighted the problems of city dwellers as diverse as New York Puerto Ricans and Indian Untouchables. However, in a desire not to contaminate themselves by value judgements, sociologists have been content with the descriptive or analytical, betraying their anthropological antecedents.

1.5. Planners had the correct professional discipline to become deeply involved in the multitude of problems or urban infrastructure. However, the dominance of three-dimensional training amongst planners foisted on the profession the master plan, sugar-cube or Lego approach to cities. The plan was laid-down and one hoped for the eventual appearance, if ever, of private and public investment to put the appropriate structures into the scheme. Since the master plans assumed a finite city population, little attention was given to a systems approach, evolutionary subsystems or incremental service networks.

Even the Regional Sciences Association, which has done the most sophisticated work applicable to urban regions, has paid little attention to the infrastructure problem.

2. RECENT HISTORY

The studies in Chapter III point out that there is validity at times in the continuum theory of history--at least as applied to research on urban infrastructure problems in developing countries.

2.1. The most up-to-date work on the provision of domestic water generally concentrates on supply but supply in rural areas. The research assumes standards of supply and devotes a degree of attention to technical details while neglecting to question the benefits of water in economic terms.

Research on the relationships between water and health is non-existent, due to the over-riding myth that you can never have enough water. The prevalence of this myth has led consultants to set extremely high standards for LDC's and thus all too frequently do a great disservice. As Part A of Chapter III substantiates, the most relevant work has been done by White; White and Bradley; and Lee and Burton. Should Bradley and Burton receive the necessary finance, their proposed study should make a contribution to our knowledge of the real effects of water (and other

factors) to the standard of health in LDC's.

2.2. The chapter on disposal of wastes similarly points out the lack of study on minimum provisions in urban areas; what little work exists is concentrated on rural problems. However, in disposal of wastes, demand studies are complicated by the dependence of demand on urban acculturation and the historical evolution of the particular city.

2.3. Domestic power supply research differs from the other elements of urban infrastructure in that there is an enormous amount of literature covering theory and application, supply and technology, which is directly applicable to LDC's. This is due in part to the fact that high standards and advanced technology are necessary for large operations, regardless of where they are located. Even the applicability of small plants has been investigated as a stop-gap measure in LDC's. The main omissions appear to be the lack of work on economic appraisal and the absence of measures of effectiveness of present policies in developing countries.

2.4. In contrast to water provision, transport studies have more documentation on demand for the service than on its supply. Of course, quality of work is a problem and little attention has been paid to land-use and land values or to the vital problem in LDC's of slow-moving vehicles. Such transportation supply studies as exist present a vast amount of technological information but ignore the question of applying such technology to the specific economic and physical conditions in LDC's.

2.5. Solutions of urban land problems are not impeded by lack of technical know-how. The LDC's have considerable experience of using labour intensive land reclamation or drainage projects to fight unemployment or famine. Yet, no solution is in sight for the task of reconciling the conflicting land needs of the newcomer with those of the economically advanced sections of the urban community.

2.6. In addition to the research gaps within each of the elements covered in this paper, the greatest area of non-research is into the relationships between the different elements and the effects of

policies in one section on the collective or individual sectors of urban infrastructure.

CHAPTER III

1. INTRODUCTION

The papers in this chapter handle the various elements of urban infrastructure in differing ways, generally as a reflection of the nature of the element.

1.1. Study A, Domestic Water Supply, presents a broad economic analysis, of both the problems involved in looking at a single part of urban infrastructure in isolation and of water itself as a key elmement. Suitably modified the questions and relationships raised in this paper are applicable in large measure to the topics which follow.

1.2. The second study on the removal of wastes emphasizes the variety and choice of technical solutions. It accepts that many of the economic pressures on waste removal are inseparable from water supply. Conversely, the domestic power supply study fully recognizes that the prevalent economies of scale limit the variety of technologies, and the critical matters in electricity supply revolve around policies of investment and

use of resources.

1.3. Part D, Urban Transportation, is similar in breadth and depth to the study of water and ties very closely to the final short section on urban land.

A. DOMESTIC WATER SUPPLY

1. PRESENT SITUATION

1.1. Water will bring immerse benefits to public health and increase economic development. This is the basic premise of the advocates of the allocation of large amounts of capital to the provision of domestic water supply. For example, the Indian Ministry of Health claims that water supply systems are:

> 'the springboard for progress in every activity which improves the material and mental wellbeing of man.' (48)

W.H.O. and Pan American Health Organization literature abound with statements such as:

> 'If a single programme were chosen which

> would have the maximum health benefit, which would rapidly stimulate social and economic development, and which would materially improve the standard of living of the people, that programme would be water supply, with provision for water running into or adjacent to the house' (86)

or

> 'Shortages of water and the frequent pollution of existing supplies impose a heavy burden on the health of peoples in the developing areas of the world, and constitute an increasingly serious obstacle to their economic progress.' (32)

1.1.2. The activities of bodies like W.H.O. are based on the 'established fact that better quality water for domestic purposes in adequate quantities improves the health of the consumer.' (87) However, the exact relationship between health and water supply is by no means an established fact. Because the role of water in health and economic progress is thought to be important, considerable amounts of capital investment go into providing sophisticated forms of water supply systems.

1.1.3. W.H.O. has established a series of long range goals for water provision: (32,90)

i) that piped water should be provided to all premises;

ii) that service should be adequate, maintaining a minimum pressure at all times;

iii) that adequate volumes of water are provided, not only for drinking but for all other household purposes;

iv) that the quality standards of the water should be at least those laid down by W.H.O. (89) (W.H.O. in fact believes that a minimum standard of safety should always be incorporated into any water supply in which it is involved.);

v) that the supply systems are protected from pollution;

vi) that the water supply systems should be administratively independent and should be run according to sound management practice;

vii) that the revenue raised from the sale of water cover all costs including capital charges;

viii) that there should be supervision of treatment plants and regular quality checks.

1.1.4. While it is recognized that these goals are not meant to be achieved in the short run, the very establishment of such goals biases the planning in underdeveloped areas toward providing very high standards of water provision. Even in a more realistic set of intermediate goals, W.H.O. stresses the importance of new house connections while recognizing that public outlets may have to be provided for a large proportion of the population. There is slender evidence for emphasi-

zing house connections rather than public outlets. It is not known whether the postulated economic growth and health benefits can be achieved by a system of community points or whether a full piped service must be provided.

1.2. The stressing of the importance of water schemes has meant that investment in water has been given high priority and has attracted a considerable amount of aid funds. Between the years 1959 and 1969, it has been estimated (87) that grants in the field of water supply amounted to 895 million U.S. dollars from international and regional agencies, plus another 180 million dollars in bilateral aid. Agencies such as the World Health Organization (mainly feasibility and planning studies), the International Bank for Reconstruction and Development, and the Agency for International Development, have all become very involved with the water supply investment programme. The U.S.A.I.D. also provides funds for actual construction and management of water supply systems, but subject to the foreign policy interests of the United States and concentrated in Latin America.

1.2.1. Despite the interest in water supply, there is very little good quantitative data on the quantity of water required by different people in different conditions. In the absence of good data, agencies and local authorities in underdeveloped areas have tended to rely on invariably high standard setting. Many writers, for example Wagner and Lanoix (78), assume that the benefits from water provision are very much reduced if supply is not available in large quantities; what is good in small quantities is even better in great quantity.

1.3. In setting a per capita supply figure for new capacity extension, it is usual for water engineers to employ one of three methods:

i) Acceptance of W.H.O. standards of 40 litres per day for standpipe provision (which with a free standpipe assumes 20 litres wastage) and 180 litres for piped water systems (multiple tap connections and considerable amenity usage). These standards are well above the figures found in studies by White and Lee of actual consumption from standpipes, and 180 litres is very generous even for the now developed nations.

ii) Reliance on standard engineering practice, derived from Western consumption patterns, when establishing their design criteria. For example, it was found in Pakistan that the normal per capita supply figure was derived from old British engineering practice. (42).

iii) Extrapolation of the present per capita consumption of households already served by the system to households about to be provided with a supply without consideration of variation in demand for water in different housing and income conditions. For example, in the Bangkok project, which is looked at in detail later, it is assumed that the consumers of water from new facilities will have the same demand characteristics as the consumers in the present system. (27)

1.3.1. Even where attempts are made to establish new per capita standards, they are often made on strange bases. For example, in a recent article by Hands (42), he rightly criticizes the present practice in Pakistan of using a general supply figure of 30 gallons per head per day, derived from British text books. But when Mr. Hands, as a training exercise for public health engineers in Pakistan, attempted to develop a new general supply figure, he based his study on the average daily water consumption in the fully serviced houses of his fellow engineers, and came up with 35.28 gallons per head per day.

1.4. Governments in underdeveloped areas tend to use western consultants to devise new urban water schemes and the consultants fees are often paid for by W.H.O. It is calculated that research and consultancy fees for a fully-fledged urban water

scheme will cost approximately 3 million dollars; but many of these expensive reports were never implemented as they were far too expensive and too ambitious for local conditions. For example, the cost of the latest water scheme for Calcutta is estimated at 455 million dollars (88), while Dacca has shelved the plans of Ralph M. Parsons and Company (Los Angeles) because the suggested scheme, while being engineeringly correct, was far beyond the financial capability of the city. (1)

1.4.1. Consultants also err in comparing the costs of their schemes with costs of similar supply systems in the western countries.*

1.4.2. It must be admitted that present engineering policy stands indicted as population expansion outpaces the expansion of the water systems: the number of people today using substandard, low quality, water sources is greater than it was ten years ago. Clearly we must rethink our approach

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* Buck in a discussion of the Johore project, which was designed to provide water for Singapore, makes the comment that the scheme's costs compare favourable with those given in Twort's discussion of the West Lothian Water Board scheme (18).

to water provision.

1.4.3. Repeatedly authors have stated that even when modern supply systems exist, they only supply a small proportion of the population, the wealthiest sector. For example, Borgesson and Bodeba (74) point out that the new modern scheme for Asuncion supplied only the high and middle income houses. Social unrest and the observable fact that water was not supplied in areas of potentially great health benefits, forced the authorities to rethink the approach to a piped water system, and resulted in a system of single tap piped connections. This may show the way for other cities in LDC's.

1.4.4. Another common feature of urban water systems in under-developed areas is that they frequently run at a loss. Water rates and unit prices are not set high enough to cover their running costs, leading the system engineers to cut down on the level of maintenance for short term savings on running expenses. Too often water is provided for high income houses, thus subsidizing the rich from general taxation.

However, Shipman (74) has recently reported that there has been a remarkable improvement during the last decade in water management practices in Latin America. In 1959, demand was outpacing supply extension and the standard of service was declining because charging schemes were not recovering operating costs. By 1969, most utilities had revised their charging systems and were at least covering running costs and were able to discharge loan debts. Some credit must go to the World Bank, anxious to ensure repayment.

1.5. Although the avowed aims of investment in urban water schemes are to improve health standards and to encourage economic development, the present policy is failing to fulfil these aims. The provision of water to only a section of the urban community cannot result in marked improvements in public health, as it is usually the very poor sections of the city--with high levels of water-borne disease--which are left unsupplied. It is ironic to find, as White (83) did in his study of East Africa, that the price of water provided by the authority is lower than the price paid for supplies of dubious character from the water carriers which are the only source for lowest income

households.

1.5.1. Unless technical aid bodies make sure that consultants devise schemes which are appropriate to the capital resources and factor endowments of the developing nations, we will have a perpetuation of the present situation where investment is heavily committed to bringing high standards of supply to a few, while the needs of the many are left unfulfilled. (28) At best, present strategy may keep pace with the increasing demands of households already supplied with piped water, but fail in coping with the influx of population into the urban areas.

2. DEMAND AND BENEFIT STUDIES

2.1. In water provision more attention has been paid to the technology of supply than to demand studies. In deciding just what level of supply is appropriate in developing countries, it is essential to have information on the benefits which result from different quantities and qualities of supply. Under the general heading of demand and benefit studies, discussion will take place on three separate topics: (i) health benefits,

(ii) economic growth benefits, (iii) demands for water. Clearly, health benefits relate to economic growth benefits since more healthy workers should be more productive. The section on demand will look at studies on variations in the quantity of water people are willing to pay for.

2.2. Health Benefits

2.2.1. It has been shown that the most common basis for advocating large scale investment in new water supply capacity is that improvements in public health will result. In fact, it is frequently asserted that 'there is no greater return on investment in public health than the furnishing of a safe water to a community.' (37) If it is accepted as axiomatic that water means health, there is a tendency to stop asking the correct questions about what level of water provision is necessary and accept Western standards. Research data supporting such ideas is extremely slender. Although it is generally agreed that a good water supply and good public health standards tend to go hand in hand, it is essential as Bradley (16) has pointed out, 'to distinguish clearly between what is known with assurance about the effects of

changing supplies upon diseases, and what is uncertain or speculative.'

2.2.2. No one would attempt to deny that under most conditions the provision of an adequate quantity of safe water should result in improvements in the health of the consumers. Diseases such as typhoid, paratyphoid, cholera, tularaemia and some forms of dysentery can be transmitted by drinking impure water. Numerous references relate epidemic outbreaks of cholera and typhoid to infected water, for example, Snow in 1855 However, it is also known that typhoid can be transmitted by food, paratyphoid is more often food-borne, and amoebic dysentery and virus diseases have not been adeuqately studied to know with certainty their chief route of transmission. In the case of diarrhoeal and gastro-intestinal disease, there is considerable evidence from studies (47, 71, 81) in the United States that the provision of a safe water supply within the home results in a fall in shigella bacteria. However, the study by White et.al. (84) clearly points out that the work on shigella suffers from sampling defects, and lacks objective control over other possible independent variables. Moreover, the

applicability of the shigella studies to the other parts of the world is still largely unknown. For example, it has been found from an experiment in Zaina (23) that gastro-intestinal diseases may not be directly controllable by an improved water supply as these diseases increased in all people above the age of two, in both an area with a pure water supply and in the control area. Virus diseases have frequently said to be water-borne, but Mosley (13), in a review of the world literature, came to the conclusion that it was likely that only one disease, infectious hepatitis was spread by water, although this was not the usual method of transmission. Diseases such as yaws, trachoma, and other skin diseases are in part diseases of personal hygiene and an increase in the quantity of water used for washing can reduce their occurence. However, the quantity of water that is required before any improvement occurs, is still largely unknown.

2.2.3. While the provision of a safe water supply seems to reduce the incidence of parasitic diseases, there are a number of examples (22, 23) where no significant decline in parasites was observed after the provision of a safe water supply.

Where diseases are spread by insects (malaria sleeping sickness, yellow fever), it appears that the critical factor is the choice of type of water supply which reduces the number of mosquito breeding sites. A piped water supply reduces the number of these sites, but water improvements which rely on wells or on roof tank storage, or on storage within the home, may well result in an increase in this type of disease.

2.2.4. More research into the relationship between health and the quantitative aspects of water supply and distribution is needed before health improvements can be taken as the sole basis for large scale investment in water supply. The essential research topics are:

2.2.4. (a) To establish quantitatively the relationship between the provision of different quantities of water and the increase in health standards of the people.* At present we lack information on the minimum quantity of

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* In White et. al. it is stated that 'attempts made to give precise values for the amount and consequences of disease show up at once the gaps in understanding.' (84)

water which is necessary to achieve an optimum reduction in the level of disease. There is no data to show whether ten gallons per head per day or forty gallons per head per day are needed to give the required health benefits.

2.2.4. (b) An essential part of any water/health project will be the establishment of realistic health aims. In the short run, it is clearly not possible for an underdeveloped area to reduce the incidence of disease to a level of that in the now developed nations and thus some criteria for choice of intermediate goals must be sought.

2.2.4. (c) There is no data on the effects on health of marginal increments in supply of water. Without knowledge of the shape of the relationship between water and health, rational choice of possible alternative water

improvements is not possible.*

Clearly, until we have got some better quantitative measure of the relationship between health and water, we have no basis for knowing whether investment in water is yielding the greatest returns to health or whether some other form of investment would yield a greater return. (Typhoid controlled by T.A.B. vaccination; yellow fever, malaria and yaws prevented by regular mass treatment). Only with greater knowledge will we be able to make rational choices between various types of investment which should improve health standards.

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* It is highly unlikely that the relationship between water provision and health will be linear with equimarginal returns to investment in water. Most authors agree that the relationship is likely to be curvilinear but there agreement ends. White et. al. for example, have said that quite often very large improvements in health can result from minor water improvements. (ie: with high marginal returns from initial investment but with strongly diminishing returns). However, neither the slope of the curve nor the point where decreasing returns set in, are in fact known. Others have asserted that there will be only very small marginal benefits from water provision until large gallonages are provided, when marginal benefits start to increase rapidly (Wagner and Lanoix and Annoni) (77, 78)

2.2.4. (d) Very little research data is available on the choice between providing many people with small quantities of very high quality water, or providing the same number of people with large quantities of lower quality water.

Traditionally, water engineers have been concerned with providing a very high standard of both supply and quality. However, some writers (for example, Bradley) (84) have pointed out that many diseases such as yaws and dysentery, can be reduced by increasing the quantity of water without improving quality. The cost of capital to improve quality in urban schemes appears to be very very small as a proportion of total capital costs, although the skills required for maintenance present considerable manpower difficulties.

2.2.4. (e) Another largely unknown factor in the relationship between health and water is the effect of different types of provision systems on health. Bradley has stated that he suspects the greatest health benefits will result from providing simple one-tapped

piped water to each home. If it is found that large quantities of water are needed for health improvements, then the distance to a water source may be an important factor. White (83) has suggested that only small quantities of water are used if the water has to be carried any distance from outside the family compound and Lee (55) in his study of bustee areas in Calcutta found similar results.* Clearly, without knowledge of the benefit to be expected from different supply systems, it is not possible to make rational investment decisions which study trade-off between cost and expected benefits.

2.2.4. (f) It is not known whether water improvements <u>alone</u> can produce health benefits or whether other linked improvements must accompany

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* White found in East Africa that it appears that low income households take an average of 30 litres per capita if they are provided with a piped water supply but this figure falls to a mean of 15 litres if water has to be carried any distance from outside the house. With carried water consumption tends to be higher if the source is within 150 feet of the household, and then appears to be the same over all the usual urban distances. Lee found the consumption slightly higher, but the distance was only weakly related to consumption levels. Conversely, Warner in his rural work found a more regular fall-off of consumption with distance, while the Kabare study in Africa showed that even with individual connections consumptions did not necessarily increase. (80)

the new water supply. In other words, it is not known whether water is a sufficient condition, or a necessary condition for improvement in health.

The slender data in existence suffers from defects of either extrapolating from temperate areas or from not holding all possible independent variables constant. For example, a common argument given as to the importance of water to health is that in the United States or Europe, typhoid and cholera incidence fell as community water supplies were provided.* However, between the years (say) 1840 and 1960, in addition to improved water supply, the level of medical provision, the knowledge of sanitation, family incomes and housing conditions all changed. One would be able to get a striking apparent association between the de-

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* In an article by Wollman and Bosch (1963) it was stated: 'The major lesson of the advent of community water supplies in the United States is the great accompanying reduction in the water-borne enteric diseases. The disappearance of typhoid fever is a striking example of this accomplishment. This experience holds promise of equal benefit in other evolving countries.' (86)

cline of typhoid incidence and the use of electric power. This defect--not holding all other possible independent variables constant--is also found in studies of conditions in LDC's.

For example Zaheer's (91) results from Uttar Pradesh are difficult to interpret, since during the study when a fall in the incidence of disease was noted, not only water supply was improved but also medical care and housing conditions. Similarly in the Zaina study (East Africa) (23) the decline in parasitic and diarrhoeal diseases after piped water supply had been provided must also be credited to the presence, for extensive periods, of doctors, health assistants, nurses and others preoccupied with health, hygiene and general environmental improvements. There was also an improvement in other indices of a healthy environment (better roofing, larger houses, improved ventilation and the lower presence of vectors such as flies, bedbugs, mice and cockroaches). (23)

Thus, intuitively it would seem highly likely that other factors such as education, improved housing, better food supplies, increased medical care and a new sewage system, must also accompany water improvements before full benefits to health can be achieved. But, here again, it is not known which other improvements must accompany water supply before full benefits are felt.

2.2.4. (g) A final difficulty in discussing the relationship between water and health is that water improvements may only reduce one set of diseases and may not improve overall health conditions very dramatically. The gain--in individual terms--is not of a life, but of a life minus the probability of death from malnutrition, respiratory diseases or other non-water related illnesses.*

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* As Carruthers has pointed out, a new piped water system may not reduce the level of water borne disease unless the population is protected from potent sources of infection: the recreational use of polluted ponds, tanks and rivers, for example.

2.2.5. In conclusion much more research work will have to be done on the relationship between water improvements and health before health benefits can be used as a major justification for large scale investment in water supply systems. As White et. al. have pointed out:

> 'the ideal assessment of the relationship of inadequate water supplies to health, is through a base-line study of disease in an area, followed by the provision of clean and abundant water alone to part of that area without permitting any other environmental changes, and then after a period of adjustment, a resurvey.' (84)

A full study would introduce different water systems in similar areas, giving families different quantities and forms of supply, while adding improvements in sewage, medical care or education, as well as the pure water

supply in certain areas.*

2.3. Economic Growth Benefits

2.3.1. While data on water and health benefits are slender, evidence on the effects of water improvements on economic growth measured by G.N.P. is even more insubstantial. It has been suggested in various water literature that there are four main benefits from water improvements which will influence the pace of economic growth:

2.3.1. (a) Industrialization, commercial development and the expansion of tourism cannot occur without the provision of a good municipal water supply.** The main evidence to substantiate this view is taken from the ex-

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* Dr. D. Bradley from the Dunn School of Pathology, Oxford and Professor Ian Burton from the University of Toronto, are, at the moment, planning a study of this type which they hope will be financed by Canada Aid. Their work will be confined to villages in East Africa, and so there is, clearly scope for similar controlled experiments in other LDC's. The Study by Warner on 26 villages in Tanzania may also yield some information on health benefits. This study aims to test 30 hypotheses of potential benefits which arise from water supply systems.

** Dietrich and Henderson have stated that industry and commerce will avoid areas where water supplies are inadequate. (32)

perience of the now developed nations, although from such evidence it is not clear as to what came first, water supply or economic growth.

It seems just as reasonable to postulate that demand for water is a consequence rather than a cause of growth in the developed nations. British industry has traditionally obtained its water from private sources. Reliance on water undertakings for a potable supply came very late in the developmental process and even today, industry takes over 80% of all its water from private sources (66). In the United States and the rest of Western Europe, there is no evidence that major manufacturing industry fails to locate in an area because of a lack of a good public water supply. It appears highly unlikely that water has retarded commercial growth as most of the large urban centres in LDC's are already established and thriving commercial centres. However, the rate of growth in the number of tourists could be affected by a known poor public water supply, but once again, much more information is necessary to determine the true relationship

between tourism and water supply.

2.3.1. (b) Improved provision of water will reduce the amount of medical care which is needed, thus releasing valuable resources for use elsewhere. Little attempt has been made to quantify these savings with the notable exception of the work of White and Bradley in Tanzania and Kenya, where they found that a minimum of 0.09 dollars per head per annum could be saved in medical expenses by reduction in water related ailments. This figure may however be subject to very wide margins of error.

2.3.1. (c) Improved water provision in urban areas may release resources of human time and energy which are tied up in travelling long distances to and queueing at water sources.

In urban areas, distances are rarely over 1,500 feet although quite a large amount of time may be spent in queueing.

Whether there are any economic gains from a reduction in the time and energy spent in fetching water will obviously depend on the

subsequent use to which the released time is put,* particularly since water fetching is frequently a feminine duty in LDC's.

2.3.1. (d) Increased labour productivity and reductions in man hour losses through illnesses and premature death will result. Theoretically, these manpower gains--by lowering the incidence of debilitating disease and decreasing unproductive water carrying--should produce increases in gross national product. Unfortunately, very little data are available on the amount of expected increase in output per worker. More information is available on the number of man days lost through illness but evidence is not consistent.

In the Zaina study before piped water was provided, an average of one man day a year was lost through water-related disease and there was little change after the provision

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* A few attempts have been made to quantify these effort and time savings, but all the known studies relate to rural situations. For example, a survey by A.V. White, 1966, attempted to estimate the calorific expenditure per water trip, and similar calculations have been performed by White and Bradley.

of a safe supply. Therefore, on the basis of this data, the hypothesis that large potential gains in labour output are to be obtained from a general improvement in health, cannot be sustained.

Moreover, the economic value of gains in man-days is very difficult to evaluate. If there is unemployment or underemployment in the urban economy, gain in G.N.P. from an increase in the number of man-days will be possibly insignificant.*

In LDC's with acute surplus of manpower, a problem in the future will be to find more job opportunities for unemployed workers and gains in strictly economic terms from water supply improvements could be minor. This unemployment point is significant, since it has been shown that the number of man days lost through water related ailments are much

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* At the Dar es Salaam workshop on rural water supplies, it was contended by a number of speakers that man day gains were an irrelevance since considerable rural unemployment already existed. (79)

greater in the poorer income categories and especially amongst the unemployed.

2.3.2. More sophisticated attempts to quantify gains from water supply improvements have tried to calculate the net productive loss, ie. income minus consumption, from premature death. Most of the studies have used cost benefit techniques in a way suggested by Dublin and Lotka (35), and by Weisbrod (85), in their studies on the economics of health. One of the most widely quoted studies of this type was by Wagner and Wannoni (78), in which enormous productive gains--800% per annum net return on capital--from investment in water were found. However,

this work has been heavily criticized.*

An investigation in Puerto Rico by Pyatt and Rogers (63), concerned with the extension of urban water facilities, was more rigorous and shows a very low net economic benefit from investment in urban water supply. It was found that during the first ten years of the operation of a new water system the benefits were less than unity. Only after

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* For example, White and Bradley point out that in the Wagner study 'loss in production was calculated on a set rate per diarrhoeal incident, but closer examination shows that over half the present earnings lost from sickness were in the one to two years age group.' Other unfortunate aspects of the Wagner work are:

i) that it assumes that all water borne diseases will fall by 90%;

ii) no discount rate was used on the value of future earnings;

iii) the assumption is made that every life saved by an improved water supply will then live on throughout its productive period;

iv) that all labour saved will be employed;

v) that average income figures are used, not taking into account that the highest proportion of deaths due to water borne diseases are in the very lowest incomes;

vi) that fetched water costs as much as water brought from water carriers.

Similar calculations have been made by Atkins (5) and this, like the work referred to above, was primarily related to rural areas.

ten years did benefits exceed costs, when a discount rate of 4% was used. If the more realistic rate of 10% is used, then benefits never exceed costs throughout the life of the new water supply capacity. Even then, it may be that the productive benefits themselves have been over-estimated since Pyatt and Rogers use average income figures to calculate net future earnings.

2.3.3. It is apparent that much more research work is necessary in order to improve our knowledge of the role of water supply in economic development. As Lee (55) has so rightly pointed out, cost benefit analyses, confined solely to the provision of a new water supply system tackles only one small aspect of the problem. Information is also required on the different levels of economic benefit to be expected from providing different

quantities, qualities and types of supply.*

2.4. Demand Studies

2.4.1. The amount of water to be supplied per head of population is obviously a crucial variable in the planning and design of any water supply system. As stated earlier, in calculating the required extent of expansion to capacity, the methods used to find a per capita supply figure are: i) acceptance of W.H.O. standards; ii) standard engineering practice; iii) extrapolation of present per capita consumption.

2.4.2. To be fair, engineers have had to rely on such general per capita consumption figures, as there is little or no available data on what socio-economic factors explain variations in water demands. However, general figures are not satis-

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* 'If the analysis is to be really effective, changes in the demand for water as economic growth proceeds and per capita income rise, must be understood. The problem in the provision of water supply is not simply that the provision of water is beneficial in itself; if there is to be a rational expansion of water supply facilities, it is necessary to know what the anticipated demands are likely to be as incomes rise and associated improvements in the living environment occur.' (55)

factory if an attempt is to be made to optimize the allocation of available resources between uses; too low a standard supply figure will become a self-fulfilling prophecy and may mean that water is not provided up to the optimal point where benefits exceed supply costs while too high standards result in wasteful over-capacity.

2.4. There are quite a number of studies of per capita variations in water use in Western Europe in North America. Similar studies for LDC's are much thinner on the ground, being confined to a study by Lee (Calcutta and New Delhi), work on East Africa (Gilbert White) and a short article by Bahamonde (10). These latter studies found that the type of supply system was itself the most crucial variable in explaining variations in water usage. This fact is highly significant for the design of distribution systems and the implications will be discussed in the following section.

2.4.3. There was also a clear and strong relationship between standards of living and the level of water consumption. Housing condition and indices of material wealth were most important than basic

differences in per capita income. In the Lee Study, differences in the ethnic composition of an area also affect demand. This finding is partially borne out by the Africa work, where ethnic differences were a significant explanatory variable when water supplies are carried, but ceased to be significantly related to piped water consumption.

These results have important implications for the use of general per capita standards in system design, especially in the heterogeneous cities of LDC's. Consideration should be placed in water planning on studying present or realistic future environments of the city, in particular, the joint planning of water supply extension and housing improvements. If the relationship between material wealth and water use holds for international variations in water consumption, then set international supply figures are inappropriate.*

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* Although intuitively the relationship between water use and G.N.P. seems likely, Lee (1969) was unable to either prove or disprove this hypothesis.

2.4.4. There are a number of conflicting opinions on the effects of prices and pricing systems on demand. Lee started his work from the assumption that price would not be a significant explanatory variable, since such small quantities of water were taken that demand would be completely inelastic. The validity of this assumption is difficult to assess. In White's study, it was found that demands were not highly responsive to price variations. On the other hand, Azpurua (7,8) has contended that higher water charges result in the poorer sections of the community reverting to impure free sources of supply.

Data from Tanzania would appear to indicate that demand for even low gallonages is price responsive. In 1966 the Government decided to stop charging for standpipe supply and in one year demand from this source doubled. (84) Even allowing for rough measurements and increased population, it still appears that the price reduction created a significant increase in demand.

2.4.5. For multiple connection systems it appears that a realistic pricing policy could reduce consumption of water. In the rich areas of some cities,

considerable gallonages of water are used for garden watering which it has been shown to have very high price elasticities.*

However, in view of the conflicting evidence, it is desirable that more work be undertaken on the relationship between price and pricing systems and demand.**

2.4.6. It is sad to report that despite a considerable literature on water supply, there are few hard facts about the demand for and benefits of water supply extension. This must clearly be a major area for future research if we are going to be

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* For example, at the Conference on Civil Engineering Problems Overseas (1962) B.N. Maggs gave the case of one copperbelt mining township in Rhodesia. When free water was available, houses were using up to 88,000 gallons per household per month, the vast majority of which went in garden watering, but after the introduction of metering, the consumption figures plunged to 8,000--14,000 g.p.h.p.m. (24)

** One small illustration will serve to show the importance to water system design of a better understanding of this relationship. In Benoni township in the Transvaal, a new water supply system was installed, serving houses which had the basic water using amenities, including flush toilets. The system was designed to provide 20 gallons per head per day, but in fact only 5 gallons per head per day were used. According to an engineer involved in the project, the basic reason for this shortfall was that the supply was metered and the consumers kept usage down to a bare minimum. (24)

able to re-think our whole approach to the provision of urban water supplies in developing countries. If the acceptance of developed nation criteria has not resulted in the necessary pace of water provision, then we must establish new criteria but on the basis of factual information rather than on intuition. Only with information will we be able to minimize the costs of provision of this infrastructure service by provision of enough water to obtain optimal benefits from the investment. When resources of capital and skilled labour are scarce, then water for amenity purposes, water to waste, and water which lies unutilized in over-expanded storage capacity must be eliminated as far as possible.

3. TECHNOLOGIES OF WATER SUPPLY PROVISION

3.1. There is a very wide range of possible ways of increasing water supplies in urban areas, from simple rain water collection barrels in individual households to a comprehensive city piped water system. It is usually assumed that in urban areas the large-scale system is the only appropriate one since the density of population allows economies of scale. Given this assumption, de-

bate centres on the issue of whether piped water should be provided to each home either with multiple or single connections, or whether a standpipe method is resorted to. Work on low cost or intermediate technologies has been oriented towards rural communities, although there is no reason why some of the small scale supply techniques need to be rejected without consideration for urban situations.

3.1.1. Village type schemes may be appropriate for sections of the urban population, if urban fringe areas are thought of as agglomerations of individual 'village' communities. Although a major breakthrough in finding new intermediate technologies is unlikely, major improvements in water provision to urban areas may occur by rethinking the applicability of some of the known techniques. Small scale approaches may not yield the same benefits as modern schemes; but some attempt at providing the very poor or newly arrived city dwellers some water is preferable to ignoring their existence.

3.2. Reallocation of Existing Supply Capacity

3.2.1. There is no reason to believe that redistribution economies cannot be achieved in LDC's. A more optimal distribution of existing supplies, could delay new construction, and postpone investment, and produce an economic gain to the community by releasing scarce resources to be employed more productively elsewhere.*

3.2.2. The first, if unpopular step, in the redistribution of supplies would be to remove the privilege of free piped water to civil servants, which appears to be relatively common practice in many under-developed areas, especially in African cities.** A second stage in the redistribution of water supply would be to introduce metering into cities where rateable value or flat rate assessments are still being used. With a flat rate charge which is the same irrespective of the

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* In the United States and Europe there is considerable scope for reallocation of supply as Hirschliefer, De Haven and Milliman have pointed out. (45)

** One example of the effects of the introduction of this measure has been found in the literature. Mr. J.H. Common, director of public works, Fiji, reported that civil servants were metered but were not paying for any of the water they consumed. However, once payment began, a reduction of 25% in consumption was noted. (24)

level of consumption, water is consumed until its marginal value in use is zero. While metering of very low consumption, low income properties may be opposed on social or health grounds, high income families should pay the true long run costs of using water in quantities well over that needed for health and hygiene.

3.2.3. Once meters are installed, price can be used as a redistributing device. Price increases may be able to hold down overall consumption and delay the need for capacity extension. Needless to say, metering alone will have little result if their maintenance is neglected and if the price set is not designed to curb consumption. An illustration of using redistribution to reduce investment is the Bangkok water system. (27) At the moment, the city provides 62% of the population with a piped and metered supply. Per capita usage per day is high, at over 135 gallons. Consultants were asked to advise on an extension to the supply system allowing for the increasing demands of already supplied households, and for an extension of the distribution system to serve 85% of the population by the year 2,000. The consultants recommended that the neglected meters

should be put in working condition and anticipated that this would reduce consumption to 115 g.p.c.d. This figure will be used as the general supply figure for the present time, but by the year 2000, 140 gallons per capita per day will be provided for all consumers. This assumes that new consumers will have the same water using characteristics as existing ones and that major capacity extension will still leave 15% of the population unserved. The unserved people will rely on minimal quantities from unimproved water sources while this huge per capita supply is being provided for the more fortunate. The possibility of holding down or even reducing the high per capita consumption by penal pricing was not considered, although if each person's consumption was reduced to 80 gallons per head per day, the need for new capacity could be delayed and the released supply could go to serve all the remaining population either by standpipe or by a single connection piped system. If even penal pricing per thousand gallons failed to deter rises in consumption, then the city would at least have the revenue with which to extend capacity without the need for world aid.

3.2.4. A third step in the reallocation of existing water supplies would be to redistribute water between waste and consumption. High levels of pipeline wastage have been reported from a number of cities in underdeveloped areas (ie: the Kampala system (67) loses approximately 35% of its supply). Use of waste detection techniques is often neglected by water authorities that are in financial difficulties, which is a short-sighted economy as waste detection and correction is one of the cheapest ways of extending effective supply. To keep a pipeline distribution system working at a high level of efficiency requires the expenditure of few scarce resources; little capital is needed and very few imported raw materials. The chief resource required is unskilled labour from the reserves of unemployed workers usually found in urban areas of LDC's. The opportunity cost of using unemployed labour to maintain water systems is zero.

3.2.5. In addition to regular maintenance, considerable water saving can also be achieved by reducing evaporation from a reservoir. Much research and experimentation has already occurred using chemicals, layers of cetyl alcohol, various forms of

wind barriers and even floating 'golf balls' to inhibit evaporation.* Although none of the methods are as yet without drawback, more time and effort should be given to the costs and benefits of evaporation control compared with the cost of capacity extension. Even the complete covering of the reservoir with polythene or butyl sheeting held down by rafts, may be economic when the benefit from postponed capital expenditure is considered. (11, 26)

3.2.6. There is also a possibility of getting more out of the existing supply system by: (i) changing the filter media in overtaxed water filter plants; (ii) using coagulation aids; and (iii) by cleaning and relining mains. This latter method may improve carrying capacity and delay the need for duplicate or replacement mains. Only when all these methods of maximizing the use of the present supply capacity have been investigated and used to their full potential should additional storage facilities be planned.

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* Mansfield, 1967, gives a useful resume of the history of evaporation control by mono-molecular layers and he discusses the effectiveness of present day methods. (12)

3.3. Investment Appraisal Criteria

3.3.1. When considering the form that new capacity extension should take it is important that adequate investment appraisal techniques are used. A recent spate of articles and books have stressed the need to take account of the differential time value of money in appraisal work.*

3.3.2. In the situation of scarce resources and positive rates of interest expenditures which occur in the future are less valuable than those taking place now. Similarly, future benefits are less valuable than immediate returns. Therefore it is important that the flows of costs and benefits which occur over the life of the water installation are reduced to a common year, either by compounding to a terminal value or by discounting--at a realistic interest rate (say 10% in LDC's) --all future earnings and expenditures back to present values. This will heavily bias investment away from water schemes which allow capacity

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* For example Krutilla and Eckstein, 1958 Hirschleifer, De Haven and Milliman, 1960, Maass, 1951 and McKean, 1958. (36)

to lie unutilized for ten or more years. Although the use of discounting appears to be widely undertaken in some engineering fields (electricity and transport), it is not widely employed in water engineering. (52, 82)

Very few of the project appraisals studied for this report appear to have taken into account the differential time value of money, and where they have, unrealistically low interest rates of 4%--5% were used. In engineering circles, the belief is still strong that no water main or storage facility can be too big; (30) demand will eventually rise to fill capacity and scale economies can be achieved. However, if the interest rate on capital is high, it may in fact be better to lay a small pipe and then a second one parallel to this at some later date, rather than laying one large pipe. In addition, by building ahead of demand, we may be committing the developing countries to present technologies, thus excluding the advantages of future innovations.

3.3.3. A second need in project appraisal is to consider the different opportunity costs of resources. In LDC's the opportunity costs of

capital, imported materials and skilled labour, are all very high, while the real cost of unskilled labour is minor or zero. Present engineering technology assumes a European pattern of resources, particularly expensive, scarce labour resources. As the resource structure in most LDC's is completely different, a system of weighting in projects, perhaps by the use of shadow pricing, should be considered. Possibly even after such a weighting procedure, modern technologies of capacity extension might be the cheapest; but without more investigation we cannot know this with certainty.

3.3.4. Developing countries should be more selective about which modern mechanical aids they accept.* As Ripman pointed out, many of the automated technologies make sense when labour costs are high, but in many cases the use of these could be foregone without loss. (69)

Conversely Carruthers has found that for large

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* ie: a man on a bike may cost a great deal less than a telemetering system but will serve the same purpose without the need for skilled repairs and imported parts.

scale capacity expansion, modern aids in digging and construction may pay, even when foreign exchange is given a premium and when labour intensive methods are costed at social opportunity cost but for smaller schemes the full use of machinery may be more expensive than labour intensive methods. (22, 23)

3.4. Technologies of Supply Capacity Extension

3.4.1.

The simplest method of increasing the amount of water available is to collect rain water in some form of a barrel or tank, commonly using as a catchment area an impervious roof (such as corrugated iron). A wide range of different types of tank can be used, the simplest being old barrels or oil drums, which have been connected together to form the required storage capacity. Purpose built tanks may either stand above ground or be sunk and lined with some impervious material (polythene, cement or butyl rubber). Although there are a number of cities where rainwater collection from roofs is already well established (ie: in Sarawak), the system has not been studied as one feasible method--perhaps interim--of increasing water supply in urban areas, despite

its place in intermcdiate technology literature as a form of rural supply extension.

Clearly the viability of the system will depend on such variables as the rainfall regime and household demand. Browne (17), in a recent piece of work, has tried to assess the feasibility of rainwater storage tanks, using a simulation model with rainfall as a stochastic variable to calculate the minimum tank size which would be required given different demand conditions. The main conclusions of the study were that, with a reasonable rainfall regime, rainwater tank collection was an economically feasible technique where per capita demands for water were low (in the order of 5 gallons per head per day); but at 10 gallons per head per day, the size of the tank needed caused costs to rise above those of other schemes. Although the study suffered from some grave data defects, the results indicate that it may be worthwhile to undertake more research into the conditions under which individual rainwater collection schemes could make a valuable, albeit temporary, contribution to the urban water supply problem.

Larger rainwater collection schemes may be suitable for groups of families in urban areas. In this case, a small surface catchment zone would be needed, not precluding additional roof collection. Experiments with these larger rainwater tanks have so far been confined to rural areas, chiefly in Botswana (for school gardens) and the Sudan (for drinking water) (51). The principle behind the rainwater tanks is that a pit is excavated, lined with some form of polythene sheeting or rubber membrane to make it watertight, and covered to prevent evaporation and maintain qual-

ity. Size and design of tanks vary* depending greatly on the rainfall regime. The maximum size of tank, 100,000 gallons could provide enough water for a small community. Much more work will have to be done, with particular reference to small groups of urban dwellings that could be treated as 'villages', before we know whether this system will be applicable to urban condi-

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* Experiments have been conducted at the Bamangwato development association at Radisele, using different designs of tanks and with various forms of lining material. From these experiments it appears that the least expensive form of lining is a mixture of mud and polythene. Costs for this lining appear to be approximately 12.50 British pounds (1968 prices) for a 10,000 gallon tank. PVC lining is one and a half times more costly and a butyl lining was found to be over five times more expensive. Butyl linings are, however, much more long lasting, although this is not necessarily an advantage in underdeveloped areas. Mud polythene tanks, originated by M. Ionides, have been designed on simple 'do-it-yourself' principles, maximizing the use of local labour and keeping to a minimum the need for imported materials and skill. Designs for these tanks vary but all rely on the idea of making a form of brick by filling tubes of polythene with a mixture of sand and cement. The polythene is then perforated and placed in a tray of water to take up moisture, so allowing the sand and cement to form a type of concrete. The excavated pits are then lined with these bricks, using mud as mortar. For drinking water schemes, longer polythene rolls, filled on the same principle, are built up into beehive structures. The capacity of the tank may be varied simply by increasing the number of beehives. Already a tank holding 100,000 gallons of water has been built. Once all the beehive structures have been completed, the tank is infilled (apart from a well shaft) with sand, which acts as a filter. It is estimated that a 10,000 gallon tank can provide enough water for approximately fifty people, if they use ten gallons per head per day. This capacity would allow for a twenty day drought period. (50, 11, 43)

tions where hither to the danger of water pollution has dominated our thinking rather than the conservation of water resources.*

3.4.2. There is already a considerable literature on the low cost forms of well construction and on simple forms of pump.** The cost of exploiting ground water on a small scale appears to vary from approximately 2 British pounds per head (Kenya) to approximately 7 British pounds per head. Carruthers has pointed out that considerable cost savings can be achieved by getting away from established design standards and designing fixtures in keeping with the local values.

3.4.3. A number of articles have mentioned in general terms the desirability of standardization of materials, an idea strongly supported by the World Health Organization. From W.H.O. statistics it appears that standardization has been successful

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* The Intermediate Technology Development Group is interested in the possibility of using this type of tank in urban fringe areas, basing their work on studies already completed in Botswana.

** The available work is well documented in the I.T.D.G. bibliography on Low Cost Water Technologies. (12)

in rural schemes and thus may be useful for urban projects. (41, 58) However as Carruthers has stressed, attention must be paid to local conditions in choice of the least cost materials and methods to use, in order to avoid mis-allocation of resources. Many of the authors who are calling for standardization are in fact asking for very high standards to be set.*

In view of the contradictory evidence on the desirability of standardization, there is a clear case for further investigation of the subject.

3.4.4. In the construction of large scale facilities a breakthrough in new low cost technology is doubtful: but, considerable savings may be achieved if the engineers reconsider standard design criteria in light of the resource structure and objectives of LDC's. Engineers usually relate their designs to professional principles, in-

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* This is typified in an article by Kollar in which he stresses the need for standardization of product by considering the quality of plastic pipes. He argues that many of the cheaper ones are not least cost since their walls are thinner and they have shorter life. However in LDC's, a short lived pipe with lower initial import cost may well prove to be the least expensive. (54)

variably borrowed wholesale from Western Europe or the United States, and they are extremely reluctant to use methods which have been outdated. (2, 33, 46, 49, 75) For institutional reasons, design standards are very slow to change and they are invariably conservative, erring on the side of producing long lives and extremely safe structures. Some of the standards set were laid down in the 1930s and have not been changed according to the changes in the quality of material. There is a need for simplicity in design, and a consideration of less than 'best engineering practice' if local materials and skills are better suited to the 'inferior method'.

In fact it is common for design simplicity to be overlooked with a tendency to build spectacular surface water collection schemes with complete treatment facilities which appear cheaper in terms of cost per thousand gallons if the opportunity costs of capital are ignored in the initial calculations.

In Britain reservoirs were built with a design life of 25 years or more but the standard of construction is so high that they are still perfor-

ming quite satisfactorily after fifty or sixty years. The point has been repeatedly made in this report that such long-lived plants are probably uneconomic in countries with very high interest rates. E.J. Davies, (29) in a review of the water supply situation in Sierra Leone, came to the conclusion that urban water schemes should have a life of less than twenty years. He gave two reasons for this: (i) that local standards of maintenance are poor and (ii) that it was extremely difficult to forecast future demands for water.

3.4.5. Desalination is by no means a low cost technology although it may prove suitable for developing countries with an extreme shortage of rainfall, low power costs or no capital shortages. It has proved extremely difficult to obtain reliable figures on the costs of various types of distillation plant. Figures from running schemes range from $1 per U.S. gallon to $20 per U.S. gallon. In a recent report by the United Nations, it was pointed out that invariably the running costs of

operational plants are well above the estimates.* At present, distillation is most viable when used in conjunction with a conventional reservoir system, using desalination only in periods of low flow or peak demand.

A great advantage of distillation plants is that they can be installed in units.** Mawer and Sheriff have shown that in certain conditions, it is cheaper to build a desalination plant than to undertake long distance transfer of water. For example in Barcelona, a distillation plant could be built in four stages over eleven years, saving

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* In a survey of eighty-seven plants in twenty-one countries, it was found that only 5% were able to produce water at less than $1 per 1,000 U.S. gallons, and 5% were costing over $20 per 1,000 gallons. From research done at the British Waterworks Association, it appears that for single purpose distillation plants, costs of approximately 35p per 1,000 gallons must be expected, and to this must be added the cost of transporting the water. Much lower costs result when desalination and nuclear electricity generation are combined in dual purpose installations, which can produce 30 million gallons a day, costing between 20p and 28p per thousand gallons.

** In a recent copy of the Desalting Digest, there was a claim by the Aqua Chemical Corporation that they had developed a plant capable of producing water at costs 25% below that of the normal multi-stage flash evaporator. In their system, sea water is sprayed over heat carrying tube bundles. The company are now offering package plants with capacities ranging from 70,000 to 500,000 gallons per day. One such plant has already gone to Abu Dhabi, to supply a controlled environment food factory. A second has been supplied to Brindisi, also for industrial use. (31)

--compared with the costs of reservoirs and 125 mile pipeline--approximately fifty-five million dollars (at a 6% p.a. interest rate) or one hundred million dollars (at an 8% discount rate).

Electrodialysis and reverse osmosis both appear to be economic methods of desalination for lightly salted water only, with costs below 20p per thousand gallons. Costs increase with the salinity of the feedwater and treatment of seawater is not yet feasible. However, in countries where there are large resources of brackish water, one of these membrane processes may well be an economic proposition.*

The United States Saline Water Office is prepared to expend quite large sums of money in the belief that a major breakthrough in desalination research may come with the use of membranes.

3.4.6. Brackish water can also be treated by permeator, based on using hollow fibres as a filter. This system has been produced by the DuPont Company and they predict that costs will be 25 cents to

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* Ely-Ramly has suggested in a recent work that the costs of electrodialysis are already comparable with those of obtaining water from other more conventional sources, as long as the brackish water has less than 4,000 parts per million dissolved solids.

65 cents per thousand U.S. gallons, including labour, power and depreciation. Israel and other countries in the Middle East are paying considerable attention to desalination techniques. In oil producing countries there is potential for using excess natural gas in desalination plants to keep costs down to a minimum. The feasibility of using desalination plants to extend already developed conventional water systems should be considered in other areas of the world.

3.5. Distribution Systems

3.5.1. It is only with the larger scale, centralized, urban systems that we need to consider the problem of distribution. Small community well schemes or rainwater catchment tanks could be developed on a fetch and carry basis. Conventionally the choice of distribution method has been between one of three systems, each with very different cost structures and possibly with different benefits: (i) standpipe connections, (ii) single connection piped water to each house, and (iii) comprehensive systems of multiple connections to each house. However, it is also possible that it will be economic to deliver water by road and the feasibility of this will be considered.

3.5.2. Urban Systems - Breakdown by component costs (in US$ per capita)

Country	Date	Supply Source	Treatment and Pumping	Distribution	Total	Mean
Brazil--10 projects	1958-61	0-	1-2	4-20	5-28	16
India--331 projects	1954-60	0-9	1-7	3-5	4-11	9
Jamaica--program	1961	7	9	37	30-50	40
United States--all	1966	3-85	8-60	110-206	-	275

Taken from White, 1972. Part of Table III-1. (84)

3.5.3. Standpipes or public fountains have much lower costs than normal piped water systems.* This is due to the lower number of outlet facilities provided and to the fact that per capita demands fro: a sandpipe source are usually lower than the demand from house connections. Lower per capita consumption means smaller pipes can be used and less storage capacity is required. As it has been pointed out in the section on benefits, the

* For example, it has been estimated that to supply Kyeni (23) with water from communal points would have a capital cost of 77,000 British pounds but private connections, even with a simple system, would cost 180,000 British pounds.

economic desirability of standpipes will crucially depend on whether the health and economic growth benefits from house connections justify the difference in cost. In addition, in the presence of a capital constraint, the decision will have to be made whether it is more beneficial to supply some people with a lot of water from individual connections or whether to supply everybody with smaller gallonages of safe water from communal points.

At the present time, suggestions that public fountain or standpipe sources should be extended are not welcomed since: -

(i) there is a feeling in the industry that water must be piped to the home before full health benefits are received, and

(ii) many standpipe sources do not recover their operating costs.

3.5.4. Even where charges for water are made, (i.e. Kampala and Nairobi), operating costs are not always recovered. Mr. Common of the Fiji Water Authority maintains that it is fallacious to argue that, because the people are poor, metering should not be employed at the standpipe. He refers to a case where a free standpipe in a Fijian village resulted in usage of 400 gallons

per head per day since the standpipe was running constantly. To avoid such waste a keeper was employed and people paid for each lot of water taken.*

3.5.5. While there is conflict over whether or not benefits of a single connection system outweigh its cost differential compared to the less costly communal point system, it would certainly appear from the available literature that a minimal pipe installation of one controlled tap per household can give an individual house connection at costs well below that of the traditional multiple tap system. The best documented example of this is in Asuncion, (14) where the 1962 construction costs of a multiple tap system were 43 dollars per head. This figure was reduced to 5-7 dollars per head if a single tap system was used. Many areas of the world also use single tap services but no cost figures have been obtained for these.

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* It has also been pointed out that, in situations of acute capital shortage, communal point systems may be the only ones that are able to ensure a chlorinated safe water supply to all the urban community. This view is taken by Carruthers, Lee and Burton. On the other hand, White and Bradley have maintained that the cost differential between providing water at a standpipe and at the home by a single connection system, is minor, whereas the difference in benefits may be great. While such conflicting views exist, it is clearly desirable that more research is done to clarify the issue.

3.5.6. If piped water is to be provided in the home, the problem arises of how to regulate demand to reduce wastage while maintaining the advantages of the supply. Some areas have tackled this difficulty by metering each connection (i.e. Karuri). However it has been argued that the cost of metering is greater than the money collected and that consumption may fall below the figure desirable for full health benefits. Also in the literature there appears the completely contradictory argument that pricing does not reduce consumption. In Asuncion, the wastage problem was tackled in a rather different way by using effort rather than money as the rationing device. The method used for this was the "Fordilla Valve" designed by Richard T. Ford. It is simply a spring loaded faucet that cannot be held or tied open and that discharges approximately one litre at a time. "By means of a simple dashpot mechanism, the device closes automatically in six seconds and must be operated for each discharge. Flow is begun by a downward push on the button and stops when the designed quantity has been discharged or the downward pressure is removed. When the button is released the faucet is ready for operation again immediately" (Borjesson and

Bobeda). In effect, this device restricts the use of water very much as does the handpump, because people will not expend energy to release more water than necessary, over use and waste are partially controlled. However, there is little data to show whether this valve results in a greater or smaller water saving than does metering, and a defect in the system is that unless whole areas are saturated with such a device, people will sell water to their less fortunate neighbours.

As White and Bradley say, until this type of valve has been tried longer and more widely, it cannot be adopted everywhere with confidence. But it does suggest a kind of improvement in technique which may have far reaching consequences in reducing the cost of meeting the world's water needs.

3.5.7. As an intermediate measure, water can be delivered by road rather than developing an extensive piped network. One form that road distribution could take is for modern tankers to deliver water to "district shops" which then deliver or sell the water over the counter to householders. This

system would eliminate the traditional water carrier who provides dubious quality water at exhorbitant prices. When the area served in this way could be supplied by pipeline, then the tankers, or lorries with barrels or tanks, could be used to serve a more recently settled section of the city.*

3.5.8. In addition to the discussion on the type of distribution system which can feasibly be employed, it is necessary to consider the more technical question of the location, type and size of pipes. A number of underdeveloped areas, with suitable climatic conditions, are already served with pipes laid on the surface of the ground.

The advantages of surface pipes are: reduced initial construction cost; decreased maintenance expenses since leaks are more easily detected and mended.

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* One neat idea would be to use lorries with removable seats for bringing people into work and then, at the offpeak period for transport, remove the seats and load up with water barrels for distribution to shops. This simple idea has not appeared in the literature surveyed to date and it certainly does not appear in the thinking of water engineers.

The disadvantages are: damage occurs more frequently when the pipes are not buried; iron pipes, with a resale value, will be stolen if they are exposed in the very poor areas; the only costs saved are the labour costs and if unskilled labour is unemployed in the economy, the social opportunity cost of its use is zero. Moreover, providing employment to the previously unemployed could yield positive net benefits to G.N.P. through the income multiplier process. As no cost data seems to substantiate or refute the arguments above, it is desirable that such cost data are collected before above ground pipe systems are accepted or rejected.

There has been considerable debate in recent years on the desirability of using plastic pipes rather than the more traditional wrought iron or galvanized steel. The arguments in favour of PVC pipes are that they are resistant to corrosion, have better hydraulic characteristics, are easy to handle and lay, and that their capital cost is usually lower than the costs of other types of pipe. On the other hand, it has been found that considerable skill is needed to flair

the plastic pipe ends.* However, a blanket recommendation on the use of plastic pipes throughout developing areas does not pay consideration to the conditions in each LDC and the local resources for producing galvanized iron, spun iron or even the old fashioned bituminously coated steel pipe. The fact that these have a shorter life (25-30 years?) would not be as relevant as the importance of saving on import costs.

3.5.9. Although in selecting the best pipe size, a study of the hydraulic variables is essential, engineers also need to consider the other interdependent parameters of time and money. It is worth noting that in the Asuncion experiment, pipes of very small size were used. The main distribution was by 2" pipe which fed a 1 1/2" and then a 1" pipe.

Finally, a 3/4" pipe was used to distribute the water to the individual households. It was found that the cost of such installation was reasonable

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* For example, in the Kampala study it was envisaged that in due course plastics would be used throughout the system.

and that the supply and pressure was sufficient to serve all the consumers adequately. The lower pressure was acceptable to the consumers and sufficient to avoid the danger of pollution from ground-water.

(N.B. The chief dangers from pollution of groundwater arise when there is an intermittent supply, since negative pipeline pressures may then be encountered.)

In addition, there is no evidence that the intermittent supply in fact lowers per household consumption. Families merely tend to store enough water to take them over the low supply period.

There is certainly much more information available on the types of supply system which can be used in urban underdeveloped areas than there is on the demands and benefits of water. However, there is considerable scope for research into the applicability of intermediate low cost technologies in urban conditions. Moreover, engineers must be encouraged to adapt their standard practices to the conditions found in LDC's, particularly, the different resource structures neces-

setating lower supply standards and the need to keep imports to a minimum. It is encouraging to note that the International Water Supply Association have recently set up a committee to consider the whole question of what standards of supply are needed in underdeveloped areas and low cost technologies.

4. MANAGEMENT STUDIES

4.1. So far we have considered the benefits from water provision and the technology of supply. The next and vitally important subject for discussion is the whole question of the implementation and management of water investments. Clearly the administration of water will involve the establishing of policy objectives and this should be done on the basis of knowledge, not on the basis of habit. While policy decisions must be linked to research into finding the demands for and the benefits of water, decisions cannot be delayed until all information is available.

4.1.1. The benefits from, and the cost of, providing different types of water service will be important variables in establishing provision objec-

tives, there will also be other major factors which will influence the decision, and which differ enormously from country to country:

a) The factor endowments of the country concerned. The term 'developing' covers a very wide range of differing national conditions, from Kuwait with a surplus of capital and power, to Botswana with very few natural resources.

b) The social or development objectives of the State. A country like Tanzania, with social welfare and income redistribution, as high priorities will not arrive at the same water provision policy as a country which emphasizes economic growth.

4.2. State objectives will be reflected in the way they allocate their scarce resources between various infrastructure services, say between water (mainly benefiting individuals) and electric power (mainly benefiting economic growth).*

4.2.1. The management of water provision must be planned on a united basis throughout the country or even

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* It is therefore difficult to see that the World Health Organization's policy of setting standard objectives for the provision of water in underdeveloped areas is a very valuable practical exercise. More useful would be an attempt to help each underdeveloped area themselves to develop their own short-term plans for the provision of water.

throughout a region. Water supply, effluent disposal, navigation, irrigation, power--all these inter-related uses of water must be planned on an integrated basis. One pattern of consumption frequently affects or even precludes some other possibility of development. (i.e. the use of a water course for a large-scale irrigation scheme may preclude the use of the same course for industrial uses or for urban consumption.) As demand for the resource increases, competition and conflict among the different users of both surface and underground supplies are likely to become accentuated.* Not only is national planning advisable because water resources are hydraulically interconnected, but also because in most underdeveloped nations there is usually an

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* In Britain a major feature of the development of the water industry has been a lack of attention paid to water planning on a national basis. Throughout the nineteenth century the laissez-faire climate restricted any extension of central control over water supply. A piecemeal unregulated development of the industry has meant that resources have not been exploited in such a way as to make possible the supplying of all the various demands for water from the most economic sources. Over the years the numerous abstractors and in situ users have produced a competitive and economically inefficient system of water supply. Despite attempts to rectify this situation since 1945, there are still considerable defects in the British management system. Judging from this experience it appears essential for underdeveloped areas to begin national water planning at an early stage. (66)

acute shortage of factors of production and thus the need to optimize their use.

4.2.2. At the level of a city the most critical relationships are between the authority responsible for water provision and those that provide housing, sewage removal facilities, transportation or other urban infrastructure services. The link between water supply and the sewage facilities is obvious:

When per capita water consumption rises much over 40 litres per day, a waterborne sewage system becomes inevitable. A multipe connection piped water system results in per capita consumption figures over 40 litres per day, and thus the cost of the system is increased by sewage facilities. Areas served by communal points or simple piped systems can usually be served adequately by the hand collection of sewage, use of cesspools, septic tanks etc. As it was pointed out in the Lagos study (53), it is axiomatic that whenever a new neighbourhood or complete community is created sewerage and water supply systems must be designed simultaneously.

4.2.3. Apart from this obvious need for co-ordination between the water and sewage authorities, a link

between planning housing and water provision is crucial. Housing standards, densities and lay-out patterns will affect the costs of water supply systems, and may determine the applicability of the low cost supply technologies. Low density, low income housing may well mean that distribution by pipeline becomes prohibitively expensive, due to the length of piping required. However, such densities may mean that there is sufficient space for individual or community rainwater catchment tanks. Conversely where land is very scarce high density low income housing, may result in pipeline distribution being the most economic method of supply.

4.2.4. These problems of co-ordination of water supply and other municipal services, underscore the neccesity for an administrative structure concerned with the overall planning or urban infrastructure services. One further point on the relationship between water provision and housing conditions concerns the supply of water to unauthorized buildings and squatter communities. Authorities deny water and other services to squatter communities in the fear that the illegal occupation will be made legitimate. However, existence of these communities cannot be ignored indefinitely.

Some solution to the provision of services problem must be found. In the case of water--bearing in mind that squatters have very little opportunity to use water, lacking the space and income to provide water-using equipment--it could be provided by either a) a number of communal points (standpipes, wells, shops etc.) or b) by distributing the water by lorry, on the same principle as a mobile shop. Neither system automatically makes the occupation legal nor lays down a "permanent" pipe network.

4.3. Financing

4.3.1. An important question in the management of any water system is how is it to be financed?--how are the capital and maintenance costs to be met? Many writers, such as Wolman, Shipman, and Koenigsberger have stressed that water provision can and should be self-financing, relieving central government funds for the financing of its non-reimbursable obligations. As Wolman has said, "If you continue as engineers to emphasize needs, to emphasize desires, and not to concern yourselves deeply with financial necessities and reimbursement, you will never provide the globe with the required water necessities". In Bangkok and Lagos for example the State has to subsidize

the water system creating a regressive form of income redistribution from the poor, who have no piped water, to the rich, while also using resources which could be used for the expansion of the system.

4.3.2. It is rare for any water utility in an underdeveloped area to accumulate a surplus over running costs, and thus finance future investments. At the same time, water engineers cannot just assume that the capital needed for supply extension will be provided by overseas aid or the central authority. To make the water utility at least partially self-financing, charges must be geared to replacement costs and not historic costs, based on the cost of past capacity extension. Invariably, these past costs are much lower and much of the cost has already been depreciated off the books-of-account.

4.3.3. Where no capital market exists from which funds can be borrowed, self-finance may have to be an important source of investment funds. However, there are circumstances in which self-financing may be inappropriate: where the external benefits of water consumption are such that, if left

entirely to private decisions, it will be under-supplied.

4.3.4. This would be the case if it were found that the optimal level of health benefit could only be achieved if large gallonages of water were supplied to all families. Undoubtedly some utilities may have to provide part of their area with a non-economic supply. However, internal cross subsidization will be preferable to subsidization from general taxation, as a) subsidies from central government tend to reduce the amount of capital that a government is prepared to lend towards new capital investment; b) cross-subsidization within the water utility will be from the rich to the poor.

4.4. Pricing

4.4.1. Pricing systems have already been discussed briefly in both the section on demand and that on supply technology. There is scant and conflicting evidence on the effect of pricing systems on demand. It appears vital that much more research is undertaken on this subject.

4.4.2. On first sight, it seems likely that a unit payment for water will minimize wastage and postpone the need for capacity extension. In areas with multiple tap connections demand should be high enough to allow the costs of metering to be recouped while unit charging will not reduce demand below the point of optimal health benefits. High peak demand may be accounted for by an increase in garden watering during the dry period. In such cases a peak load pricing system may be appropriate than a new capacity extension. In the low income sections of the city, the choice of pricing system is much more problematic. Unit pricing would be inappropriate under any of the following conditions:

a) if pricing reduced demand below the level required to achieve health benefits.

b) if a charging system made no difference to the level of demand.

c) if the extra cost of operating a unit charging system exceeded the cost savings in capacity extension which resulted from a lowering of demand.

4.4.3. It has been suggested that a single tapped piped system using "Fordilla" valves can deter wastage of water in the same way as metering. In this

case, the payment for water by a fixed monthly or even annual charge can reduce the initial capital cost and the running cost by eliminating meters and their maintenance. There is considerable disagreement on the feasibility and desirability of charging for units of water obtained at a standpipe. If research revealed that unit charging is the optimal solution, such a solution may be unacceptable to some countries, such as Tanzania, where the policy is to supply free water to all consumers. Consideration must be given to alternative methods of financing but very few hard facts are available to determine which pricing system is appropriate under which conditions. It is suggested that a prime need in future research is to inves igate the relationship between pricing and demand.

4.5. General Management

4.5.1. In the management of a water utility in a LDC, the officers must interpret their functions much more widely than would be appropriate in developed countries. The functions should include:

4.5.1. (a) Education

There is some evidence that health benefits from water provision can be increased markedly if rudimentary sanitary education is introduced at the same time as a new water supply. If this proves to be the case, the water authority should employ people for teaching the use of water and institute close cooperation with the health authority.

4.5.1. (b) Training

The water authority or possibly groups of authorities, must undertake an active training programme to develop a supply of skilled workers such as plumbers.

4.5.1. (c) Management flexibility

Water authorities may have to be prepared to:

-- own fleets of lorries, possibly jointly with a transport company;

-- own and administer water shops, wash houses and possibly communal bathing and toilet facilities;

-- to own a stock of water supply equipment such as guttering and water tanks which it hires out;

-- possibly manufacture some of its own equipment such as meters and piping;

-- investigate the desirability and feasibility of self-help and intermediate technologies in urban water projects.

4.5.2. In view of these broader management needs, it is suggested that a move away from an engineer dominated authority may be appropriate. Economists and sociologists have vital roles to play in the investment and social planning of water supply. With the interest in self-help water schemes, as

evidenced by W.H.O. assertations*, these other disciplines are more than ever necessary. It is only when some experimentation has been done that we will know whether self-help schemes can be feasible in urban areas.

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* W.H.O. claims that if water supply schemes are maintained by central authorities, the local feeling of responsibility towards the scheme is destroyed and benefits are reduced. Others have said that self-help induces a greater sense of community in an area, providing sociological side-benefits.

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B. REMOVAL AND TREATMENT OF SOLID AND LIQUID WASTES

1. DEMAND AND BENEFIT

1.1. The demand for efficient and hygienic removal of domestic wastes in developing countries is not an individual demand. It is a demand by the community and most importantly, a demand which is a direct function of density.

The removal of wastes in a dispersed settlement present few problems of hygiene or resource priorities. Systems such as bore hole latrines, dry latrines coupled with simple compost production are adequate in rural conditions. However, the mere lack of land renders such economical solutions invalid in cities.

1.2. A second characteristic of the demand for organized removal of wastes is the correlation between length of stay in the city of a newcomer and the demand for sanitary services. This one might say, is a demand created by education; in this case education in urban life style. At this point only does demand for removal of wastes become an individual demand--directly as a result

of education .

1.3. Thirdly a point arrives in overall urban density at which the residential and job density (including industry and offices) create a sudden powerful demand for very capital intensive high technology solutions. This aspect of demand for removal of wastes is as easily predictable as is the growth of the cities themselves.

1.4. The benefits of an efficient system of waste removal are obvious in terms of disease. For example, the spread of the following diseases, all faecal-borne, can be virtually eliminated:

bacillary dysentery
typhoid fever
paratyphoid fever
cholera
amoebic dysentery
bilharziasis
hookworm
ascariasis
and (possibly) poliomyelitis.

The curtailment of such diseases spreads the benefits beyond the preservation of human life and favourably affects such things as medical services and employment.

1.4.1. Less obvious benefits of an effective waste removal programme might include:

-- the potential control a system exerts on urban sprawl;

-- the improved environment of the urban area;

-- the impetus it could give to the general up-grading of neighbourhood areas;

-- the attraction of serviced areas to industrial development and

-- the possibility of recycling and utilization of urban wastes.

2. ENGINEERING TECHNOLOGY

2.1. Collection of Faecal Matter

The four systems of collecting faecal matter are borehole latrines, dry latrines, wet latrines and water closets. All are in use in developing countries although the last and most sophisticated of the four, is only feasible where there is an adequate supply of water.

2.1.1. Bore-hole latrines are widely used throughout developing countries but are not favoured where the manurial value of the faeces is highly assessed (6). However, they are of simple construction (7) and if care is taken that they do not contaminate water supplies, they can serve for many years and effectively dispose and collect wastes. Dry latrines also have this joint function of disposal and collection (7) and, in addition, have been used where there is a need to conserve faecal matter for agricultural use (6). Dry latrines can prove a longer term solution to the problem, providing that there are adequate supplies of dry material (soil, sawdust, peat or suitable compost) to absorb urine and faeces. Where there is a minimal supply of water (approximately 5 gallons per head per day), even if this is the soiled water from washing etc. this can be used to dilute the faeces in latrines in place of adding an absorbing material.

2.2. Collection of Refuse

2.2.1. In Europe a household of three will produce between 11 and 17 kilograms of refuse per week, the

great bulk of which is ash, paper and putrescible organic matter. No reliable statistics are available for developing countries on either the amount of refuse produced, nor on the proportions of ash, etc. It may be assumed however that the putrescible content of the refuse in developing countries will be high and the ash and paper content low.

This high proportion of putrescible matter makes it necessary that refuse be stored in covered containers through all stages of passage from the home to the disposal centre and that it is removed at frequent intervals. For example, in some densely populated parts of Israel there is a daily collection of refuse which is thought necessary due to climate and the content of the refuse (8).

2.2.2. A daily service for the collection of refuse need not necessarily be more expensive than a less frequent service provided that the householders cooperate by contributing to some extent their own labour. One system is to provide conveniently situated communal bins, of sufficient capacity for the needs of those served. A daily collec-

tion of the communal bins, by vehicles fully utilized, can be provided at no greater cost than a less frequent collection service. Within a community where the rate of accumulation of refuse is low, small covered containers would be sufficient to serve each household.

2.2.3. Even as simple a system as that described above cannot be implemented without reliable figures on the quantity of refuse in the developing country. This will have to be established to allow the capacity of transportation vehicles to be determined. When ash-free refuse of high organic content and high density is being dealt with, it is doubtful that huge and expensive vehicles designed for dustless loading of large quantities of bulky refuse would be required. Open bodied vehicles of suitable capacity, with covers, will meet the requirements.

2.2.4. It is interesting to note that despite the development of highly sophisticated and costly appliances for street cleaning, it is accepted that a street orderly with handcart, brush and shovel can provide an efficient service at a relatively small outlay of capital expenditure (9) such a

service in the 'public' domestic areas can often provide the added benefit of employing the unemployed.

2.3. Transportation of Faecal Matter

2.3.1. Hand carriage, truck, tankers and sewers are the four main methods of transporting faecal matter. Hand carriage is only hygienically effective if the collector has reached a high degree of dexterity (6), and it does, of course, not cope with the problem of urine disposal. Truck removal of night soil from dry latrines is facilitated by an adequate, but not excessive quantity of absorbent. The trucks must have sufficient cover (sliding cover, tarpaulines, or a layer of absorbing material) to avoid exposure to the atmosphere. Tankers with vacuum pipes present no problems in the transportation of the content of wet latrines.

Sewers are required for water closets and may be extended to wet latrines not connected directly to them.

2.4. Treatment of Faecal Matter

2.4.1. The simplest, but in most ways the least desirable method of treating faecal matter, is the drying of it to form a cake for use as manure (6). This method is unwholesome and results in high losses in nitrogen and foulsmelling drying areas.

2.4.2. More effective treatments can be devised if there is sufficient land available to assimilate the night-soil from latrines. Although this is far from likely in the densely populated urban areas of LDC's, one quote from Picton (circa 1924) gives a good indication of the kind of thinking that some regard as applicable to 'overseas' problems (12, 13).

> "The whole plot would be treated as one garden, and one whole timehead gardener, with the help he needed, would be responsible for its cultivation. The daily removal of the closet earth and its use as manure--its immediate committal to the surface soil and its light covering therewith--would naturally be amongst his duties. A gardener using manure of great value, not a scavenger removing refuse; a 'garden rate' paid by each householder, an investment productive of fresh vegetables to be had at his door, and in one way or another repaying him his outlay, not to speak of the amenity added to his surroundings, instead of a 'sanitary rate' paid to be rid of rubbish--such are the basis of this scheme."

2.4.3. Should adequate collection and transportation prove economically viable there are opportunities

for the use of night soil as fertilizer for commercial farming, although there are problems of pathogenic organisms and the storage of the night soil during growing seasons. (10)

2.4.4. The treatment of sewerage offers several possible techniques: irrigation, dilution, the use of septic tanks, biological treatment, oxidation ditch.

(a) Irrigation schemes present collection problems and transportation difficulties similar to those posed by the use of night soil as fertilizer. However in hot climates where rainfall is low and evaporation is high, sewage as irrigation may make a significant contribution.

Wylie describes a successful irrigation scheme operated in Melbourne, Australia covering 26,000 acres using 61,000,000 gallons of partially treated sewage per annum in an area where the normal rainfall is 18 inches per annum and evaporation the equivalent of 45 inches (14). Isaac tabulates the limiting rates of application imposed by different classes of soil and subsoil. (19)

(b) Easy access to rivers, lakes or the sea provides a convenient but limited means of treating and disposing of sewage (15, 19). While a large volume of natural water will sometimes be able to assimilate a limited quantity of sewage for a limited time, without pollution more often the sewage will require treatment before being discharged.

(c) The Septic tank may be described as the

simplest form of sewage treatment.* However its limited use--houses or small communities--makes it of dubious value in rapidly growing cities. (19, 7)

(d) Through the action of anaerobic and aerobic bacteria, the biological treatment of sewage provides for the extraction of heavier solids in suspension by sedimentation and the reduction of the finer solids and those in solution to inoffensive substance. The biological stage of the process may be carried further in percolating filters or in aeration tanks.

The activated sludge process** although less demanding in land, is so demanding on scientific and technical skill that even in developed countries its application can hardly be justified for populations of under 30,000. It has become almost standard practice for populations over that figure. A good deal of work has been done in India on

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* It provides only for the retention of the sewage in a tank of simple construction for between 24-48 hours, when the heavier solid matter in suspension settles on the bottom while the lighter organic particles form as a scum on the top. Within the tank the solid matter is subjected to anaerobic decomposition. The liquor coming from the tanks may be disposed of through field drains. When well designed and not overloaded these tanks may operate for many years without desludging but generally sludge will have to be drawn off every 2-6 months. A special form of septic tank, the Aqua Privy, was invented in Indonesia. It operates on the same principle of anaerobic digestion, is situated directly under the latrine and requires even less water than the septic tank.

** This process, treatment in aeration tanks, was devised by Dr. Gilbert Fowler of the University of Manchester in conjunction with Arden and Lockett of Manchester City Council. First operated in 1914, the process resulted in sludge with very high content of organic nitrogen, and was developed to increase the manurial value of the sludge.

this process.*

(e) There are some processes for the treatment of liquid sewage, such as the oxidation ditch (16) which can provide partial treatment to the sewage at a cost of about one third of that required for full biological treatment (17).

(f) Whenever sewage is subjected to a purifying process, whether it be by septic tank, oxidation ditch or biological treatment, a sludge is produced. This sludge contains a high proportion of the organic matter contained in the sewage liquor before treatment, concentrated in a fluid containing between 2% and 5% solid matter in suspension. The sludge has similar characteristics to that of night-soil coming from wet latrines and is produced at the rate of about one third of a gallon per head per day. It has a significant manurial value and can be used for land irrigation (14) or dried in lagoons, or by vacuum filtration, presses or heat treatment (19) to form a cake suitable for agricultural use.

2.5. Treatment of Refuse

2.5.1. The disposal processes to which domestic refuse is subjected in developed countries--generally tipping--are not generally applicable in developing countries, because the large quantity of putrescible organic matter creates tips which are filthy, foul smelling and a potential source of

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* Subsequently in Cawnpore, India, Fowler continued to apply his talents to the conservation of organic wastes for use in agriculture (20).

water pollution (21)*

2.5.2. Wastes containing a high proportion of dry materials of high calorific value, which is characteristic of the refuse accruing in developed countries, can be disposed of hygienically by incineration (22, 26), with or without providing for the recovery of heat produced during burning (27, 28). However, because of the high content of putrescible matter in the refuse of developing countries, its calorific value will be low; it will not be readily combustible, and will not therefore lend itself to disposal by incineration even if the high cost of that could be met.**

2.5.3. Domestic refuse, with a high putrescible organic matter content, can be disposed of most readily,

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* Refuse having a relatively high content of solid inert materials (in some developed countries the ash content alone is as high as 50% of the total weight) when deposited in layers can be readily consolidated to create good land from waste land.

** The capital cost of providing an incineration plant for burning refuse is now 50,000 British pounds per ton/hour capacity, which means the financial charges alone will be about 2 British pounds per ton of refuse burned.

particularly in dry hot weather, by stacking it in windrows some 6 feet high and 12 feet across at the base and allowing it to decay. If loosely stacked the wastes will decompose rapidly under aerobic conditions with a minimum of fly-nuisance and the decayed wastes can then be screened, producing rough but valuable compost (6).

2.6. Utilization of Wastes

2.6.1. A distinction is made in this study between (i) the use that is made of waste materials as a by-product of some treatment process of the crude wastes and (ii) a treatment process designed to exploit fully the potential value of the wastes for a particular need. Thus while the manurial value of crude refuse is limited (30), its value can be increased merely by pulverization. However even when the pulverized wastes are allowed to decay before use, their potential value is not fully exploited. Domestic refuse and human faeces must be treated together by composting under aerobic conditions to exploit their potential value as organic manures.

2.6.2. (a) Composting is a natural process which de-

veloped countries have acquired from developing the techniques of countries. The research in developed countries has done no more than reveal facts which explain the procedures followed in the traditional composting methods of the developing countries (31).

A great deal of work has been done on applying the ancient art of composting to the treatment of town wastes, and the application of the process to suit widely differing conditions (35, 36, 37)*

A wide range of methods have been developed, from manually operated plants to highly sophisticated capital intensive plants (38, 39, 40).

Although some municipal composts are produced in developed countries from a mixture of domestic refuse and sewage sludge, in a great many cases only domestic refuse is used.** The dry refuse can only take up about one fifth of the wet sludge and even when the sludge is dewatered (to a moisture content of around 75%), there is still some difficulty in establishing good composting conditions with a mixture of the wastes. This difficulty will arise to an even greater extent with smaller quantities of refuse of higher moisture content in developing countries, but would not necessarily apply in the case of night soil from dry latrines.

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* The work done in India (32, 13 pp. 39-50, 31 p.206) South Africa (33 pp. 38-147) and China (6 pp. 151-255) have been well recorded.

** This may be explained by the fact that the departmental authority responsible for refuse disposal often has no responsibility for the disposal of sewage sludge.

Dymond* suggests that the water-hyacinth could be grown in water enriched with sewage effluent, harvested and dried to make good this deficiency.**

2.6.2. (b) There is evidence*** that the whole environment within a composting mass is antagonistic to pathogenic organisms, but the exposure of putrescible organic matter to the atmosphere produces conditions suitable for prolific fly-breeding and the production of foul smells. The use of insecticides and deodorents reduces these effects but has to be controlled if the value of the wastes for food production is not to be destroyed (47). Some work has been done in the control of fly-breeding and in design of simple mechanical fly-traps (6, 33)

(c) The purpose of treating organic wastes by composting is to produce humus, the basis of soil fertility (45, 46). Composts are not a substitute for chemical fertilizers and their manurial value should not be measured by their content of nitrogen, phosphates and potash (46). A high humus content in soils

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* In Appendix B of Van Vuren's "Soil Fertility and Sewage" (33).

** Scott makes a similar suggestion for China (6) and Hills suggests a Russian Comfrey would be suitable (41).

*** Rudolf et.al. have reviewed literature on the occurrences of pathogenic organisms in faecal matter (10) and the thermal death points of these organisms has been established (35). Their thermal death points are within the range of temperatures which can be otained with aerobic composting where they are maintained for a very much longer period of time than is required for the destruction of the organisms (42, 14). Howitt (43) established that some pathogenic organisms are destroyed by aerobic fermentation and Grainger (44) concluded that eelworm cycsts are not only destroyed but are completely disintegrated by the process.

is required if erosion is to be avoided (48), and with a plentiful supply of humus forming composts available there would be less need for artificial chemical fertilizers (49).

There is also some evidence that crops grown on soils matured with organic manures and composts have a special nutritional value (13, 54).

It has been established that composts made from town wastes contain a wide range of trace elements (14) and many of these are essential to the growth of healthy crops (50, 51). A popular suggestion is that these trace minerals in composts accounts for the ability to support crop growth. However this has been countered to some extent in recent years by the suggestion that excessive quantities of trace minerals in composts could create toxic conditions in soils (52). The presence of excessive minerals (e.g. lead and zinc) only comes about when trade or industrial wastes are added to domestic wastes for compost production. While there is some evidence of a slow build up in soils of these minerals after regular, heavy application of municipal composts, there is no evidence of this causing toxicity to the crops (53).

2.6.2. (d) Although the farmer may be prepared to pay more for good composts than he would for any other type of organic manure coming from municipal wastes and may even be prepared to pay still more as he gains experience from its use, the income deriving from sales will not cover processing costs.

Municipal composting is not a lucrative

business in developed countries*, nevertheless it is seen as providing a means of promoting the economic growth of a country.**

By investing in the production of composts from domestic wastes a health authority (i) disposes of the wastes hygienically; (ii) improves soil fertility thus promoting food production. It is not known whether the same investment in a plant for the production of artificial chemical fertilizers would make an equal or greater contribution to food production but such an investment would add greatly to the cost of waste disposal.

2.6.3. The production of natural gas from sewage sludge treated in "Digesters" is standard practice in

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* In Holland where large scale compost production from municipal wastes has been proceeding under government sponsorship since 1932, the output at the beginning was largely used for land reclamation purposes. By 1940, however, agriculture was taking up to 90% of the total output with only 10% going to land reclamation. Today horticulture is the biggest user, taking some 43% of the total output with only 15% going to agriculture and the remaining 42% going to land reclamation schemes, public parks and playing fields. The composts are now being produced in different qualities to suit the purpose for which they will be used. It is estimated that the soils of Holland could take 1,000,000 tons of compost a year. The 200,000 tons now produced annually is sold at a price which is established by the normal process of supply and demand (recently 12 D. Fl. per ton).(55).

** In France and Germany the central government gives the municipalities grants of 30% of the invested capital while in Czechoslovakia there is an official policy providing for a composting plant being built for every community of over 50,000 people (57).

sewage treatment in developed countries.* The sewage sludge or the contents of wet latrines from a population of 10,000 produces enough gas to drive a 20 horse power engine all day long.

To treat large quantities of sludge, costly digesters have to be built which, in temperate climates, have to be fitted with heating coils to maintain a temperature of 80 degrees Farenheit. Where there are alternative sources of power there is no demand for the gas produced and it is often burned to waste. In countries where there is a shortage of fuel and an ambient temperature of around 80 degrees Farenheit is obtainable, natural gas could be produced spontaneously from sewage sludge or liquid night soil (contained in airtight cells, simply constructed of prefabricated blocks). The rate of gas production per head of the population could also be increased by the addition of organic wastes from domestic refuse.

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* Digestion takes place under anaerobic conditions at a temperature of around 80 degrees Farenheit when natural gas is produced at the rate of 0.6 to 0.8 cu. ft. per head of the sewered population (19). The calorific value of the gas produced is about 630 British Thermal Units per cubic foot, which is superior to that of coal gas.

The manurial value of organic wastes is not impaired by being subjected to anaerobic digestion for gas production, and in Europe since the war, considerable progress has been made in the technique of methane gas production from farm wastes.*

It is estimated that the dung from one cow will yield enough gas to provide the domestic power needed for a family of three and that the stock from a farm would be able to provide all the power required for the numerous farming processes (58, 59).

2.6.4. The reduction of organic matter contained in sewage to soluble salts effected by sewage treatments can result in stimulating the growth of green plants (algae) that are present in the receiving water, and thus apparently frustrating the purpose of the treatment process (60). However, advantage can be taken of this phenomenon. Algae are rich in protein and their growth can be encouraged in shallow ponds exposed to sunlight

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* In 1952, the number of installations in France had risen to 1,000 and the number was increasing at the rate of about 200 per year.

if partially treated sewage is discharged into them. Such a scheme provides for the removal of the solids suspended in the crude sewage and the discharge of the sewage liquor into the ponds. The algae is harvested and sterilized by heat treatment (the heat being supplied from methane gas produced from the digestion of the sludge extracted from the crude sewage). After drying in open beds a high protein animal food is produced which, with some further processing can be made suitable for human diet (61).

The process is the subject of a thorough research programme being carried out by the ASIAN Institute of Technology, who have just published a report (62) on the work done.*

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* Six volumes were produced:

(1) Summary Report on Research Conducted during 1969-70.

(2) Factors Affecting Algal Yields from High-Rate Oxidation Ponds Treating Sewage.

(3) Open Air Sun Drying of Algae.

(4) Harvesting of Algae through Chemical Flocculation and Flotation.

(5) Flotation as a Method of Harvesting Algae from Ponds.

(6) Application of the Sewage Grown Mass Algal Culture Process to the Asian Urban Environment.

3. IMPLEMENTATION AND ORGANIZATION

3.1. It is essential that a programme of education in matters concerning personal and public hygiene should go hand in hand with the implementation of a sanitary service. With an appreciation of the advantage to health which a clean urban environment brings, the establishment of a satisfactory sanitary service based primarily on a "self-help" basis could be expected to develop into a more labour intensive service and ultimately to more capital intensive schemes as the economy of the country strengthens. This applies particularly to the collection of the wastes but it also applies, even if only to a lesser extent, to disposal and utilization.

3.2. The provision of a service by incremental growth is feasible when the service is labour intensive and each increment of growth is related to the working capacity of some unit which involves capital investment within that labour intensive service. For example: A refuse collecting service which provides full work for a refuse collecting vehicle can be readily extended by the purchase of a second vehicle. However, if there is not

sufficient refuse to ensure that the second vehicle is worked to full capacity, then no economic advantage is to be gained by extending the service.

3.3. The removal of wastes has been accepted as a function of the local authority in developed and developing countries. However, this acceptance has not resulted in the implementation of workable solutions in the case of developing countries. This is due to two main reasons:

(a) In developed countries the growth rate of cities was lower and the ratio between middle/and/upper class population and working class population has been higher than is now the case in the developing countries. This comparatively slow city growth took place during periods of industrialization and expansive capital formation making it practical to establish public utilities. In the developing countries today over 90% of the population is below the level of taxation and thus cannot contribute to any form of capital formation for civic purposes. Their cities therefore cannot finance capi-

tal intensive activities. A solution is made more difficult by the inherited fiscal systems which are more often than not unsuitable to the problems of the cities they are meant to serve.

(b) When the cities and local authorities of the cities in developing countries took on the responsibility for removal of wastes they did not realize they would need jurisdiction over an area of land larger than the built-up area in order to dispose or utilize the wastes created by the built-up area.*

4. SUMMARY AND SUGGESTIONS FOR RESEARCH

4.1. The methods of waste collection, transportation, disposal and utilization of wastes as practiced in developed countries do not consider ecological effects and have consequently resulted in widespread environmental pollution. New systems are

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* In countries influenced by Spanish administrative practice, the city does include the city region but no examples have come to light which indicate that advantage has been taken of this structure.

now being developed, designed to abate environmental pollution but they are capital intensive, demanding on scientific and technical skills and thus inappropriate for developing countries.

4.2. A suitable programme for the education of the public on the principles of personal and public hygiene may help to increase life expectancy and lower the incidence of disease as much as the introduction of future sanitary schemes. Additional provisions will be needed for the convenience of the urban population and the protection of the natural environment.

4.3. When it is appreciated that the world's resources of water and air, however vast, do not have a limitless capacity for the disposal of wastes, then mere disposal must give way to utilization, in the form of composts which improve soil fertility and the use of organic salts from treated sewage for the production of animal and human protein-rich food.

4.4. The administration of a sanitary service should be designed taking these basic facts into account at all points of its development. No such ad-

ministrative arrangements exist in the sanitary service of any developed country.

5. RESEARCH NEEDS

5.1. The research which is being done on the collection, transportation, disposal and utilization of wastes is fragmentary, dealing only with special aspects of the problem. This research is of great importance, but there appears to be a need for a special study as to how all aspects can be integrated into a complete sanitary service.

5.2. While there is little hope of a technical breakthrough in this field, applied research in resource recovery--particularly the use of oxidation ponds and photosynthesis processes--should be explored further, perhaps through a world conference on the subject.

5.3. Ways should be investigated of adapting the N.A.S.A. work on resource recycling in spacecraft to the large scale, economically constrained

situations under discussion.*

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* It is understood that Professor K. Boulding at the University of Colorado is working on the adaptation of N.A.S.A. research for the solution of urban infrastructure problems in the U.S.A.

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(44) J. Granger, "The Golden Eelworm", Research Bulletin No. 10, West of Scotland Agricultural College.

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N.B.

Assessment of Selected Technical References, with further references.

A. Collection of Faecal Matter.

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Fuller descriptions of various types of latrines are available, but these for the most part refer to those already in use (8, 9, 10) and little, if anything appears to be being done in the mass production of well designed latrines making use of impervious synthetic materials for example, or in the design of wet latrines, with soiled water used for flushing in accordance with a W.H.O. recommendation--"No higher quality water, unless there is a surplus of it, should be used for a purpose that can tolerate a lower grade" (11).

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Analysis of a Technical Aid Programme", Washington D.C. 1951.

(iii) V. Rainakrishna, "Role of Health Education in Environmental Sanitation Programmes"; Unpublished paper prepared for the W.H.O. Seminar on Environmental Sanitation, Beirut, Oct. - Nov. 1956.

(iv) "Environmental Determinants of Community Well-Being" Proceedings of the Special Session held during the Third Meeting of the P.A.H.O. advisory Committee on Medical Research, June 1964.

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(xii) H. Yeager Clark, Well Pollution and Safe Sites for Bored-Hole Latrines, The Malayan Medical Journal, Vol. IV No. 4, Singapore, Dec. 1929, pp. 118-125.

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B. Collection of Refuse

(8) J. Sumner, "The Storage and Collection of Refuse - Methods, Practices, Technical Developments and Trends - An International Survey", Conference Paper International Association of Public Cleansing 1967.

(9) Summary of National Reports on Street Cleansing, International Association of Public Cleansing 1967.

The information contained in these references are of no significant value in the establishment of a refuse collecting service in developing countries. The collecting vehicles used in developed countries are being elaborated to minimum air borne dust and to increase the pay-load when bulky refuse is being handled. It is significant however that the very substantial savings which can be made in collecting costs when refuse is picked up at conveniently sited points in-

stead of from each house is increasingly emphasized. The increasing loading difficulties caused by cars parked in streets, demonstrate how efficient such a labour intensive service can be.

C. Transportation of Faecal Matter

The use of vacuum tankers for the transportation of liquid faecal matter, requires no special reference but it should perhaps be noted that while a service based entirely on the use of such vehicles is suitable for incremental growth, it is nevertheless a capital intensive service and the transportation of liquid faecal matter can be accomplished much more economically by pipe line, even if these have to be operated by pumping.

D. Treatment of Faecal Matter

(6) J.C. Scott, "Health and Agriculture in China", Faber and Faber 1952.

(12) L.J. Picton, "The Economic Disposal of Excreta: Garden Sanitation" British Medical Journal, February 1924.

(13) A. Howard, "An Agricultural Testament", London University Press, 1947.

The views of these writers, based as they are on practical experience are sound (although Scott

does question whether the production of faeces cakes can be justified on sanitary or conservation grounds) and are widely supported as being applicable in developing countries.

(i) W. Wilkie, "Jordan's Tropical Hygiene and Sanitation", Bailliere, Tindall and Cox, Third Edition, 1956.

(ii) E.J. Hamlin, "Sewerage and Sewage Disposal in Sub-Tropical Countries, with Special Reference to South Africa and Mauritius", Inst. Civil Engineers 1952.

(iii) "Individual Sewage Disposal Systems: Recommendations of Joint Committee on Rural Sanitation", U.S. Department of Health Education and Welfare, July 1954.

E. Treatment of Sewage

(a) Irrigation

(14) J.C. Wylie, "Fertility from Town Wastes", Faber and Faber 1959, pp. 51-55.

(19) P.C.G. Isaac, "Public Health Engineering", E. & F.N. Spon Ltd. 1953, pp. 119-120.

The irrigation scheme described is applicable to developing countries where similar conditions exist. The limiting rates of application tabulated by Isaac are applicable in temperate climates and would require to be adjusted for application under other climatic conditions and extended to cover the crop grown and/or stock carried.

(b) Dilution

(19) P.C.G. Isaac, "Public Health Engineering", E. & F.N. Spon Ltd., 1953.

(15) J.C. Wylie, "The Wastes of Civilization", Faber and Faber, 1959.

The conditions described apply in developed countries and to the waters of temperate climates and cannot be applied strictly to conditions in developing countries, where circumstances will sometimes not permit as high a degree of purity in natural waters to be achieved and some degree of pollution, assessed by European Standards, will be permissible (1, 2, 3, 4, 5).

Further References

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(ii) V.A. Shaw, "An Assessment of the Probable Influence of Evaporation on Oxidation Pond Design and Construction" C.S.I.R., South African Branch, Reference Nr. R.D. 89.

(iii) J.K. Neil and G.J. Hopkins, "Experimental Lagooning of Raw Sewage" Sewage Industrial Wastes, 28 (11) Nov. 1956.

(iv) L. Abbot, "A Scheme for the treatment of raw sewage in oxidation ponds", Paper presented at C.S.A. Conference, water treatment, at Pretoria, Sept. 1960.

(v) W.J. Oswald, "Fundamental Factors in Oxidation Pond Design", Conference on Biological Waste Treatment, Manhattan College April 20-22, 1960.

(c) Septic Tanks

(19) P.C.G. Isaac, "Public Health Engineering", E. & F.N. Spon Ltd. 1953, pp. 140-142.

(7) Manual of Army Health, H.M. Stationery Office 1965 pp. 206-207.

These tanks are emminently suitable for the treatment of limited quantities of sewage in developing countries, both in their simplest construction or in the rather more elaborate form of the Imhoff tank.

Further References

(i) United States Department of Health Education and Welfare, Public Health Service "Manual of Septic Tank Practice: developed in co-operation with the joint committee on Rural Sanitation", Washington D.C. Public Health Service, Publication No. 526, 1957.

(d) Biological Treatment

(19) P.C.G. Isaac, "Public Health Engineering", E. & F.N. Spon Ltd. 1953.

There is a plethora of publications covering the biological treatment of sewage mechanically, which reveal a continuing trend of elaboration aiming at the production of clearer effluents to meet the requirements of the waters of temperate climates. The high degree of purification achieved will not generally be required in developing countries (unless the appli-

cation of the process is required as the first stage of treatment for the recovery of sewage as potable water). The high capital cost and the scientific and technical skills required in operation will be further impediments to its use in developing countries.

It should be noted also that the reduction of organic matter in sewage to soluble salts, effected almost completely by full biological treatment, can lead to difficulties with eutrophication when the effluent is discharged into a natural course.

Further References

(i) R.A. Vollenweider, "Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication", Organization for Economic Co-operation and Development, Paris 1968.

(ii) O. Jaag, "Problems in Community Waste Management - Present Trends in Research on Water and Sewage", W.H.O. Public Health Paper No. 38, 1969.

(e) Oxidation Ditches

(16) O.G. Ashcroft, Split Channel Pasveer Oxidation Ditches Surveyor 133, 4016, pp. 34-38, 1969.

The recent development of this relatively low cost sewage treatment process should have wide application

in developing countries. It appears to be a protected process, developed in Holland by the Research Institute of Public Health Engineering T.N.O., Delft.

(f) Sewage Sludge

(14) J.C. Wylie, "Fertility from Town Wastes", Faber and Faber 1955, pp. 63-64.

(19) P.C.G. Isaac, "Public Health Engineering", E. & F.N. Spon Ltd., 1953, pp. 157-163.

The treatment of sewage sludge either in liquid form or as an air dried cake for use as a manure could have a wide application in developing countries but the drying of sludge to a cake by mechanical means is a capital intensive refinement.

F. Treatment of Refuse

As has been said in the text of this study, the refuse treatment processes practiced in developed countries are not suitable for adoption by developing countries.

G. Utilization of Wastes

(1) Compost production from Refuse and Night Soil and/or Sewage Sludge

(32) Jackson & Wad, "The Sanitary Disposal and Agricultural Utilization of Habitation Wastes by the Indore Method", Indian Medical Gazette, Feb. 1934.

(13) A. Howard, "An Agricultural Testament", London University Press 1947, pp. 39-50.

(31) L.E. Howard, "Sir Albert Howard in India", Faber and Faber 1953, p. 206.

(33) J.P.J. Van Vuren, "Soil Fertility and Sewage", Faber and Faber, 1949.

(6) J.C. Scott, "Health and Agriculture in China", Faber and Faber, 1952.

The published works of these authors, and the convictions expressed are all based on the work done by Howard in India but nevertheless, they have all tested Howard's theories in the field before expressing their convictions, and for that they are important and demand respect.

There is some evidence that after Van Vuren completed his work in South Africa, further developments in municipal composting tended to follow capital intensive processes developed in Europe, with the consequence that progress towards a wider application of the basic principles of composting with domestic wastes appears to have been retarded.

Few, if any, reports have come from India in recent

years, on the development of composting schemes as operated by Howard in the early thirties, except to the effect that the basic principles he enunciated are still fully respected.

Just at the time when Scott had reduced the work he had been doing in China, to writing, the "Bamboo Curtain" came down around that country. Now that news is once again being allowed to come out of China, it is known that there has been, during the intervening years, an intensive programme on the virtues of personal and communal hygiene and it would be a matter of great interest, which might carry great advantages to other developing countries, if it could be established to what extent Scott's views have been accepted.

The highly sophisticated plants designed in developed countries, with a view to producing composts from municipal wastes in five days by the aid of mechanical appliances and with the use of cultures (in which they have not been successful) will have no application in developing countries. The use of some of the earth handling equipment now available, could however facilitate the production of composts when large quantities of wastes are being processed.

(2) Methane Gas Production

(19) P.C.G. Isaac, "Public Health Engineering", E. & I.N. Spon Ltd. 1953.

The provisions described by Isaac for the production of methane from sewage sludge are typical of those operating in developed countries. Although the quality of the gas produced is excellent, the rate of production against the demand for power, is not sufficient to make it viable commercially in developed countries.

Nevertheless, the production of methane gas from organic wastes can be achieved by quite simple means, as is revealed in the other two references: -

(58) F. Mignotte, "Gas du Fumier a la Ferme", La Maison Rustique, Paris.

(59) H. Martin-Leake, and L.E. Howard, "Methane Gas from Farmyard Manure", Albert Howard Foundation of Organic Husbandry.

Methane gas can be produced from organic wastes in a couple of discarded oil drums; it can be distributed compressed in cylinders (as with calor gas) or by pipe line.

There appears to be a wide field of possibilities inviting investigation into methods suitable for the

exploitation of this natural process in developing countries where fuel and power are in short supply.

(3) Protein Production from Algae

(62) "The Treatment of Sewage and Production of Protein through the Mass Culture of Algae", Research Program of the Asian Institute of Technology, Sept. 1970.

This is an important work, extending to six volumes of meticulously planned research on an advanced pilot scheme scale. The work is based on research which was taken through the theoretical, laboratory and pilot scheme stages by a strong school of investigators of the University of California in the late 1950s and early 1960s and by work sponsored by the Carnegie Institute of Washington D.C. and others during the same period, all of which is fully acknowledged in this first report of the Asian Institute of Technology.

The significance of this research may be assessed by the fact that Prof. W.J. Oswald of the University of California as early as 1960 saw it as the "closed cycle" system of waste disposal in the space age, which at that time might cost 40,000 British pounds per capita, but which in tropical climates could be achieved at a substantially lower cost than that of

conventional sewage treatment processes applying in developed countries.

C. DOMESTIC POWER SUPPLY

1. INTRODUCTION

1.1. Of all the subjects being considered in this infrastructure study the supply of electricity is potentially the most capital-intensive. In housing or transport, solutions appropriate to capital-rich countries can often be rejected out of hand: the same cannot be done in the supply of electricity due to enormous economies of scale in the generation and distribution of electricity (1). This has been universally recognized by LDC's and their development programmes have been shaped accordingly.

It is not mere emulation of existing industrialized technology, nor the publicity given a handful of major capital-intensive schemes (Aswan, Cabora Bassa, etc.), giving a totally misleading impression of the overall development of electricity systems in LDC's.

1.2. The countries we have looked at in detail (2) will not have to face the problem of electricity supply from scratch:

(i) Many of them already have significant national or regional distribution systems.

(ii) Many already have extensive urban distribution systems--if only for industrial needs; and in some, the problems of rural electrification have also been partially resolved (3).

(iii) They have considerable experience of pricing policy in practice, of the problems of supply technology and maintenance, and of the importance (and difficulties) of demand forecasting.

(iv) Rapid expansion of demand from all sources is forecast, making large-scale capital-intensive solutions more likely.

1.3. Given this situation, there is only a very limited place for the isolated incremental solution of domestic urban electrification problems, and the large capital-intensive solution will be favoured. The role of incremental solutions depends upon a wide range of supply and demand factors, and in each case there will be a range of competing solutions to the given supply problems. The isolated incremental solution may be economic:

(i) Where isolation of the community, combined with a low overall demand in the area, makes transmission from a central large site uneconomic. This is generally a rural problem, outside the scope of this survey.

(ii) Where need is urgent and, although a capital-intensive solution is thought desirable in the long term, there is a need for 'stop-gap' measures. (The period between the decision to build a large new plant and its commissioning may be 5 years or more.)

(iii) Even within a large-scale development programme, there may be a role for small-scale generation to add flexibility to the timing of new capacity. As will be argued later in this paper, the cost of incorrectly estimating future demand may be very heavy (and particularly obvious, in the form of under-utilized fixed assets if demand has been over-estimated). Governments may, therefore, prefer to build large-scale low-cost plants to meet a pessimistic demand forecast, leaving small scale quickly-built or existing mobile generators to help out if demand is, in the event, higher. Overall costs per unit of output will be higher but the authority will, as compensation, have reduced the risk of leaving expensive capital idle.

(iv) Where need is urgent but unlikely to be permanent, e.g. in refugee camps, or in squatter communities.

2. DEMAND

2.1. The economic allocation and utilization of resources to meet a measurable demand requires accurate forecasting. In the case of supplying

electricity, the forecasting of demand is often difficult. One is likely to be serving a number inter-related markets (of which the urban domestic market will be one) with an existing pricing policy. Also, because of the long gestation period for new plant and the capital-intensive nature of many of the possible supply solutions, the planning period for which forecasts have to be made is likely to be long, a factor which increases the uncertainty attached to overall and aggregated forecasts of the demand for electricity. This also increases the cost of inaccurate answers. The faster demand is expected to grow, the more appropriate a capital-intensive solution and (probably) the less flexibility in the timing of new capacity. If the forecast is too low in the event, some demand remains unsatisfied--if too high, fixed resources are left idle.

2.2. The supply authority will be concerned not only with the overall level of demand but also, of course, with its distribution during the day. Because electricity cannot be usefully stored it will have to establish the size of likely demand peaks. Whether it is worth meeting these peaks and accepting that generating capacity will be

underutilized for the rest of the day will depend on a number of factors--and a pricing policy which to some extent irons out the peaks, by forcing the consumer to face the full cost of meeting his demand, is of course possible. Regulations of demand through pricing, however, may not always be thought desirable for every class of consumer:

(i) The pricing policy in a number of LDC's seems to be operating under social constraints (4)--such as a wish to help small domestic users--which limits in practice the scope for regulating demand through price.

(ii) Consumer ignorance of the subtleties of complex tariffs may blunt pricing as an effective regulator.

(iii) The more complex the tariff, the more costly are the necessary metering devices.

2.3. The forecasting of urban and rural domestic demand which in LDC's often account for over a quarter of total demand presents its own problems in addition to the ones discussed above in relation to overall demand.*

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* In addition there is a 'collective demand', primarily for street lighting, but this usually accounts for well under 5% of total demand.

In contrast with industrial and commercial demand, domestic needs are not likely to be related directly to the growth of G.N.P. Demand for electricity from most sectors is likely to rise faster than G.N.P. (5), to judge from past experience. However, the growth of incomes is only one determinant of domestic demand for electricity. For example between 1950 and 1959 domestic energy consumption (temperature corrected) in the U.K. rose by only 1% p.a.; between 1959 and 1965 the rate of growth nearly trebled although G.N.P. rose only a little faster and there was no major change in pricing policy (6).

2.4. Thus, whether domestic urban demand is being looked at in isolation, or as part of the overall demand for electricity, it may be very costly in real terms to adopt simple forecasting methods--such as the extrapolation of past trends, which ignore such factors as consumers' attitudes towards interruption and variability of supply. Domestic demand is affected by a number of social and economic factors, which have ramifications in associated sectors and are affected by these sectors. For example, the availability of suitable domestic appliances will depend upon

the state of home industry, the extent of credit facilities, the cost and availability of imports, etc. The pattern of home ownership may mean that tenants are discouraged from installing their own appliances. Consumers' fears of instability--particularly in the currency--may encourage them to prefer tangible possessions.

2.5. The need for information on such points must be common to many areas of planning. This emphasizes the fact that for Government policy to be internally consistent, there must be more than a common rate of discount and time-horizon. In developed market-orientated economies, consumer surveys have done much to improve demand forecasting and to bring out the inter-relation between sectors of the economy--what a change in one area implies for the others (7).

2.6. In the U.K., a number of pioneering surveys of this sort were conducted during the Second World War to fill the gap left by the fact that pre-War statistics were both few and irrelevant. The Political and Economic Planning's 'Report on the Market for Household Appliances' for example drew together and analyzed survey data which aided:

(1) Manufacturers in pricing and design policy.

(2) The Government, in suggesting what credit facilities and income levels would be necessary to obtain a mass market in particular appliances.

(3) Housing policy, by bringing out people's priorities in post-War housing.

(4) The gas and electricity utilities, in demand forecasting.

Of course, the pitfalls of market research are well-known but too much has often been made of them. The applicability of such research to LDC's has not yet been properly tested and apart from a centralized and paternalistic central planning mechanism, there may be no other way of ensuring that goals of policy in one area are not thwarted elsewhere in the economy.

3. PRICING

3.1. A great deal of work has been done on the theoretical aspects of pricing policy in electricity supply, because the existence of an economically rational pricing structure is an essential for optimal resource allocation (8). Unfortunately much of it has been concerned with the intricacies of marginal-cost pricing and 'second-best'

without applying these principles to concrete problems (9). More worrying is that although information on the (often very complex) tariffs in various LDC's is available, relatively little is known about how these tariffs are arrived at and what social and political considerations (such as the need to provide finance for other projects from a surplus earned by the supply of electricity) affect them (10). Although inter-country cost and price comparisons are notoriously difficult, comparisons of tariff structures, use of funds, etc. might be more feasible.

3.2. The problem is complicated by the location of the supply bodies in the public sector (apart from industries generating their own electricity and the unusual cases of privately owned supply companies such as exist in Hong Kong). The literature suggests that, as a result, a number of social and political issues cloud the atmosphere in which the supply authorities have to work (11). Many of these issues are likely to relate to the poor, especially the urban poor. Such provision of services on social grounds--e.g. the supplying of electricity below cost to the urban poor--imposes a financial cost upon the

authority and that cost should be isolated and clearly shown in the authority's accounts. (12) If this does not happen, there is no incentive for a government to weigh up accurately the costs and benefits of the social policies it is following; and the authority, to meet its financial targets, is likely to resort to cross-subsidization. This 'unnecessarily' distorts market mechanisms and makes future pricing and investment decisions more difficult to approach in an economically rational fashion.

3.3. Many writers have argued that the State should be wary of excessive interference with the authority's operations (13). The most desirable form of control is provided by the setting of realistic, internally consistent, financial targets and by the careful analysis of results against these targets. Fortunately, a fairly comprehensive 'Manual for Government Accounting' was published only last year by the U.N. aimed directly at the LDC's (14). The methodology is there. What is needed is information on how closely present practices correspond to these 'guidelines' and what have been the economic consequences in particular LDC's of their own practi-

ces.

3.4. The determination of prices is a subject upon which some agreement in principle exists. Given that a pricing policy has to be adopted, and that it should be as 'rational' as possible, then much of the theory behind marginal cost pricing becomes a useful tool rather than dogma. For example, there would probably be considerable agreement with the proposition that for new electrification schemes, price overall should not be less than long-run marginal cost. (15) This still leaves considerable scope for price differentials between peak and off-peak periods of demand, (16) recovering installation costs over time rather than immediately, meeting given social aims, and so on.

3.4.1. Setting price higher than long-run marginal cost may be preferred--for instance to restrain demand, or to provide finance for other projects. Setting price below L.R.M.C. (following any price policy which leads to persistent deficits) will occur only in very exceptional cases.

4. UNCERTAINTY

4.1. There is a formidable mathematical literature on the subject of decision making under uncertainty (17). Many investments are so small that one can justify a 'rule of thumb' allowance for uncertainty (e.g. by arbitrarily raising the required rate of return upon capital). However, the size of many of the investment decisions in the field of electricity supply is such that a more explicit allowance for uncertainty may be worthwhile, although few LDC's as yet attempt such an allowance.

4.2. On the supply side, major uncertainties relate to the frequency of plant breakdown and the rate of future technological advance (18), both of which should be allowed for in criteria for investment appraisal. In the case of demand, we have already shown the uncertainty which is likely to be attached to demand forecasts. The supply authority may well react to this problem by making a range of demand forecasts and if indifferent to an overestimate of x% and an underestimate of the same amount, the central forecast is the one which is likely to be taken.

4.2.1. However, there may well be a preference for fail-

ing to meet demand fully (particularly domestic demand, which does not aid economic growth directly) rather than have underutilized capacity.

4.2.2. If so, the authority may adopt a large-scale solution to meet a pessimistic forecast and turn to small-scale power generation to supplement this should demand prove higher. Whether in fact this will happen, will depend upon:

(i) technical and cost factors;

(ii) whether decision-making criteria have been sufficiently considered for values to be ascribed to the desirability of particular results;

(iii) the present cost of ignoring (or inadequately treating) uncertainty--(19).

It should be stressed that electricity supply will be only one of the many areas in which the element of uncertainty is likely to be important.

5. SUPPLY

5.1. There is a vast amount of literature available on the engineering and economic aspects of supplying electricity (20). Although only part of

it has been written specifically for LDC's, the technical methodology is available. Less certain is (i) whether the data available in LDC's are sufficient for the evaluation of competing solutions to a given problem; (ii) what the cost of the gap between the ideal and the actual is, and (iii) how this gap can best be narrowed. There are a number of points in investment appraisal that complicate the issues in LDC's:

(i) that power supply authorities are competing with other sectors for scarce resources;

(ii) that, as on the demand side, many other sectors are directly affected by the authorities' decisions and affect its decisions.

5.2. A simple example of this is shown by the Ghana Volta River Project (21) where the need to supply large quantities of electricity for smelting aluminum and the size of the hydro-electric 'opportunity' in the area meant that decisions on, say, how best to supply electricity to the local urban and mining populations could not be taken in isolation from the main project.

5.2.1. A second example is suggested by the possibility

of producing and transmitting electricity to a dual standard with regard to tolerance on voltage and frequency.* This would involve conventional standards for power users demanding finer tolerances and a second standard for domestic use. The system could be such that uniform high quality would be attainable in the long term. The initial possibility--that in the short term appliances might be designed to operate over greater ranges of voltage and frequency--might be discussed with the international electrical plant and appliance manufacturers. This type of solution would, of course, be easier in the presence of a large, independent capital goods industry in the LDC's and active trade in such goods between them--as pointed out in the section on transport.

5.3. We have already mentioned the problem of 'second-best' solutions and, to obtain a manageable topic, we must abstract from these on the supply

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* This would be, in effect, the acceptance of advanced technology as being the more efficient whilst recognizing that many refinements which a developed country might regard as necessary are, at least in the short term, dispensible in an LDC.

side by assuming that planning outside electricity supply follows the same criteria and methods of project appraisal. Given, then, that the required rate of return, the time horizon (22), etc., is given, the authority is faced with a familiar problem of optimizing an objective function-cost minimization, which necessarily involves cost comparisons between competing technologies (23).

5.4. The importance of correctly specifying the costs involved in various projects hardly needs emphasis; and, in doing this, one is concerned with the opportunity-costs rather than the monetary costs of employing resources. LDC's are familiar with the proposition that the opportunity-cost of employing otherwise idlelabour is zero; they may be less aware (there is little information available on what is done in practice) of the need to specify the real foreign exchange cost involved both in the initial expenditure and in the running of the project.

5.4.1. For example, some 80% (24) of the initial expenditure on a nuclear plant in an LDC may be in foreign exchange; the percentage for a fossil-

fuelled plant is perhaps 70-75% while, for a hydro-electric scheme of comparable size, the foreign exchange component may be only about 35%. In addition, foreign exchange considerations apply to running costs. For many possible projects, fuel will have to be imported. On average, if there are no indigenous fuel resources, the foreign exchange costs of running fossil-fuelled plants has been shown to be 2.6 times greater than for nuclear plants (25); again, hydro-electric schemes are favoured by this consideration.

5.5. Of course, the size of the supply problem is also extremely important--this note has already emphasized the importance of economies of scale and dangers of underutilization of resources, which is an inevitable risk given the indivisibilities (of plant size) usually involved in low-cost electricity supply (26). This factor may mean that the familiar objective function of cost minimization is restated in terms of minimum capital requirement (which, if the true capital, foreign exchange and other costs have been estimated, will come to the same thing).

5.5.1. Provided, then, that the true costs of resources are measured and accurate discounting and similar methods are used, the techniques of economic appraisal at present used in industrial countries to identify the best choice of new plant are applicable to LDC's (27). The answers, however, may be very different and, by and large, there are few technical constraints on their implementation.

6. SMALL-SCALE POWER GENERATION

6.1. Although new electrification schemes have for some time been large-scale and capital-intensive in many LDC's, the overall picture of power supplies in these countries is rather different. For example, a study of India in 1959 showed that cattle provided nearly as much power as all other sources of energy combined; and that non-commercial fuels, such as firewood and dung, provided more heat than all other sources of power (28). With such a diverse range of sources and uses of energy there may be cases in which small-scale power generation is of particular value when consideration is given to the probable elimination of transport and transmission costs, and

foreign exchange difficulties. There are four sources needing further research:

6.1.1. Water. Indications are that large schemes are economic as are small schemes if fuel costs are high. Drawbacks include: lack of siting flexibility and the need for adequate water throughout the year. Nevertheless water power could be a useful fuel saving device when coupled with thermal plants even if the supply were only of an intermittent nature.

6.1.2. Wind driven electrical generators. These have the same advantages as water plants, a free source of energy. They are also cheap to install but are restricted to favourable sites (e.g. hilltops) and require high annual average windspeed.

6.1.3. Solar. With annual intense sunshine, the potential of this source of energy is obvious. Unfortunately, the production of motive power from the sun is usually very expensive, although research and development has produced some economical applications without the intervention of electricity generation (e.g. water heating,

distillation, space heating.)

6.1.4. Organic Wastes. New commercial fuel resources (wood and peat) could be widely used for heating and power production. There are, in many developing areas, considerable quantities of organic wastes at present put to little use (sugar cane wastes, corn cobs, rice husks, coconut shells and even dried vegetation), all of which have a calorific value about half that of coal. Provided they are cheap to collect, they can be used for power production in one of the following ways:

(i) As dry fuel to fire a steam-driven plant

(ii) To generate producer gas to use as a supplementary fuel in a dual fuel engine

(iii) Through fermentation to produce methane which can be used as a domestic fuel or to drive an engine.

Another potential fuel source is the use of human and animal waste-products to form methane.

6.2. The state of development of these possibilities has been reviewed in a recent U.N. publication

(29), but the economic--as opposed to the engineering--possibilities seem to have received little attention. One suspects that, for an electrification scheme of any size, small-scale generation would not be economically feasible, except perhaps as a stop-gap measure taking the form of a series of diesel electric mobile generating sets, using a simple distribution system employing local labour and materials. However before such a statement could be made definitely, a wide range of economic considerations would have to be quantified.

7. CONCLUSION

7.1. Electricity supply is a major and complex question which cannot be divorced from the consideration of supply to any particular section of it (such as the domestic urban market). The engineering problems in theory and practice as they affect LDC's have received considerable attention in the literature, although some technical progress in this field is possible. Amongst economic considerations, however, the applications of a theoretical framework to improve the pricing structure, the treatment of uncertainty,

establishing the real cost of capital, foreign exchange and other inputs, is less advanced. The major difficulty is that evidence of what is at present done is not available in sufficient detail to assess the cost of not following more economically rational policies. Only when this has been remedied and the problems in new electrification schemes correctly specified, will it be possible to get the best out of the existing engineering technology available.

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(12) For example, in the way that Unremunerative Rail Service Grants are paid by the Government to British Rail, to compensate for losses incurred through keeping specific lines open for social reasons.

(13) Reports of the Select Committee on Nationalized Industries have, in the U.K. admitted the need for a clearly defined area of managerial freedom.

(14) "A Manual for Government Accounting" U.N. ST/ECA/130 1970.

(15) M.J. Farrell, "In Defence of Public-utility price theory", Oxford Economic Papers, new series Vol. 10 1958.

(16) O.E. Williamson, "Peak-load pricing and Optimal Capacity under Indivisibility Constraints", American Economic Review Vol. 56 1966.

(17) Risk is defined as a situation in which the outcome is uncertain, but the probability distribution of out-
& comes is known with certainty. At the other extreme, where nothing whatever is known about the probability
(18) distribution we have the case of pure uncertainty. Most actual situations fall under neither heading strictly but contain a 'combination' of the two. For example, plant breakdowns constitute, primarily, a risk because the probability of breakdowns is likely to be fairly well established. The problem of obsolescence, however, is nearer the extreme of pure uncertainty.

BOTH risk and uncertainty should be specifically allowed for in project appraisal. Relevant literature includes:

K.J. Arrow, "Alternative Approaches to the Theory of Choice in Risktaking Situations", Econometrica Oct. 1951.

W.J. Baumal, "Economic Theory and operations analysis", 2nd Edition Prentice Hall 1965.

(19) T.W. Berrie, "Appraising the Economic Worth of Alternative Projects", Electric Review 181 13 (1967).

(20) Basic topics concerning siting, generation, transmission etc., not covered in the text, are well documented.

(21) A.B. Mountjoy, "Industrialization and Under-developed Countries", Hutchinson 1966.

(22) Because of the very different length of life of competing technologies, the choice of a time-horizon will be by no means easy.

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D. URBAN TRANSPORTATION

1. INTRODUCTION

1.1. The aim of adapting and developing transport technologies to a stage where they can meet the distinctive needs of cities in the less-developed countries cannot be achieved by considering technology in isolation. Of all urban infrastructure systems transport is perhaps the system which has the closest interaction with the pattern of land-uses in the city. This pattern is both itself strongly influenced by the transport network, and in turn determines the best geometry and the economically best technology for the transport system. Accordingly, this discussion, while primarily intended to appraise research on the development and evaluation of transport technology, does so within the more general planning framework explained below. Such a framework is especially needed when attention is focused, as it is in the present study, on the need to provide efficiently for the integration of low income 'newcomers' into the urban economy.

1.2. Since any general studies of urban transport must

begin by analyzing the activities that give rise to movements, and the conditions (for instance of income and accessibility) under which these activities take place, this chapter begins by considering the 'demand' side of the transport problem. The discussion covers comprehensive transportation studies and land-use planning in so far as this has a direct relationship with the demand and need for transport. The evidence of research so far on urban transport demand in less-developed countries is then used to provide a basis for considering appropriate patterns of supply of transport services, covering both the technologies and their organization and management, and for a discussion of methods of evaluating proposed systems. With both 'demand' and 'supply' in perspective, it becomes possible to review current research and practice on the pricing, finance and regulation of urban transport systems; and these problems are discussed in section 5 of this chapter.

2. THE DEMAND FOR, AND BENEFITS OF, URBAN TRANSPORT SERVICES

2.1. The measurement of transport demand is a task

which can be tackled on a number of different levels. In theory, it raises issues which can only be resolved by the simultaneous analysis of land-use patterns, economic activity and spatial relationships, using a 'general systems' approach and employing the mathematical tools of location analysis (1, 2, 3) and transportation modelling (4) in use or under development in the industrial countries. Some current work (in Santiago) is being devoted to testing the validity of these analytical tools in an 'underdeveloped' situation (5), but much more work of this kind is needed. Without at least the framework of such an approach, a search for a 'technological fix' may often be doomed to frustration (6).

2.2. While such a comprehensive approach may be considered over-ambition in many less-developed countries on grounds of cost and data availability, among other reasons (and see section 2.4.2. for a further discussion of these issues), some of its elements are clearly of great practical importance. For example, would the institution of rapid-transit service into Lagos island as recommended in the 1964 Report (7) to some extent defeat its own aim by producing greater

centralization of service employment on the island, and greater dispersal of residential areas, thereby worsening the acute 'tidal flow' transport problem at peak hours? Would major primary highway improvements under the intensely constrained geographical conditions of Rio de Janiero (14) lead to a deterioration of transport service due to a major shift away from public transport and the realization of a large volume of 'latent' demand for travel? Clearly such questions cannot be dismissed just because of the acute data limitations which exist, or because of the limitations on what can reasonably be spent on transportation studies, as well as probable deficiencies in our theoretical understanding of the activity-structure of poor cities. The questions must be identified and tackled using at least some form of 'systems' approach if not formal modelling.

In fact, a number of comprehensive transportation studies (or studies aspiring to be comprehensive) have been or are being carried out in developing countries using various elements of a systems approach. And in more cases still of course traffic engineers, planners and administrators

are doing 'ad hoc' studies as best they can with the available resources and 'know-how'. A critical review of some current efforts of both these two kinds is given below.

In presenting this review it is worth pointing out that in a number of cases traditional land-use planners have developed proposals for settlement structures designed to minimize congestion problems and optimize the use of transport infrastructure. This has occurred even in cases where such a broad view has not been taken by those with formal responsibility for transport questions. Several cities in less-developed countries have evolved plans for multi-centered urban areas or 'metropolitan regions' on the grounds that central area problems in very large 'radial' cities may in fact defeat even the resources of industrialized societies. One such multi-centered plan has been semi-officially proposed for Nairobi (15, 16) and Richard Meier and others have persuasively argued the merits of such solutions for some major Indian cities (60).

2.3. A number of significant generalizations can be drawn from the transportation studies which have

been reviewed (including references 7-14). The cities under consideration can usefully (though rather arbitrarily) be divided into two groups. The first group, which we might term 'semi-developed', tend to be characterized by significant levels of car-ownership (over more than say, 20 motor vehicles per 1,000 inhabitants), the existence of a substantial network of metalled roads with a relatively adequately organized public transport system. Much the largest component of road traffic comprises four (or more) wheeled motor vehicles. Typical of this group are Santiago (8), Tel-Aviv (9) and Caracas (10); the group as a whole can probably be identified with the cases where, to quote the Survey's Terms of Reference (V), 'skills and resources will develop rapidly enough to provide the 'standard' infrastructure systems of the future'.

A second group of cities in less-developed countries comprises those, typically in countries where mean per-capita GDP is less than perhaps $200, which have a lower economic level and usually weaker infrastructure. Unfortunately, countries in this group have some of the largest cities in the world--the Calcutta Metropolitan

Area, with well over 6 million inhabitants, Shanghai with perhaps 7 million, Cairo, with nearly 4 million, or Djakarta with over 3 million. Smaller cities in this group, for instance Kaduna in Northern Nigeria (11), while suffering less acutely from some of the problems of scale (notably in transport and health) are often less well-equipped with infrastructure and public transport.

2.4. The Higher-income cities

2.4.1. The bulk of the literature concerning studies in these cities seems, broadly to fall into two categories--'applied research' in the form of comprehensive transportation studies; and the day-to-day work, or ad-hoc studies, undertaken by local transport planners--mainly traffic engineers.

If we begin with studies and reports in the latter category, we can sketch out the usual type of diagnosis which is given of the transport 'problem'. "Levels of car ownership and volumes of trip-making are high and, in the major cities, rising steadily towards "Western" levels. Con-

gestion is acute and imposes strong external "diseconomies" on buses and trucks as well as cars, with corresponding economic losses. Accident rates are often high. In order to meet this situation, we need to strive towards the traffic engineering 'best practice' of the developed countries--a package involving geometric improvements and control measures to increase throughput at bottlenecks; parking controls and major increases in roadspace."

One can read statements like the following, referring to the conventional ring-and-radial motorway system being developed for Buenos Aires: "..the projected Buenos Aires - La Plata turnpike....will join the Capital of the Argentine Republic with the City of La Plata, Capital of the Province of Buenos Aires, and together with the Northern and Western Accesses will constitute part of the freeway system. This we believe will solve the traffic problem in Great Buenos Aires". (12, 13).

Such statements may seem optimistic in view of the growing awareness in the industrial countries that travel demand is decidedly elastic to the

degree of accessibility provided, and that even if an equilibrium can be reached at high levels of car-ownership and road provision (with very dispersed and thus costly land-use patterns as in Southern California or parts of the mid-western USA), this may be an extremely wasteful 'solution', involving massive capital expenditure and resulting in economically and ecologically inefficient land-use patterns.

In a developing country, with acute resource scarcities and often a highly unequal distribution of income, these implications of a road-oriented strategy may be decidedly unfavourable to development objectives.

2.4.2. To put matters in perspective, it must be noted that a number of 'higher-income' cities have seen a need to emphasize public transport in their plans--often mainly because of sheer physical constraints as well as demand conditions. This is particularly the case in Caracas (10) and Rio de Janiero (14) for example, where constricted, mountainous and, in the former case, strongly linear, geography favours fixed-line public transport.

One further characteristic of many transportation studies in 'higher-income' cities that should be noted is a very strong emphasis on safety, very characteristic of traffic engineering priorities. In at least one case (Rio de Janiero) this has resulted in an attempt to ban the lotacoes, a 'jitney' (or communal-taxi) service (see below, section 3.3.2)--which carried some 700,000 journeys per day in 1964, immediately before the ban--on the grounds they were dangerous and not amenable to regulation. There has been a striking absence of serious cost-benefit studies of such decisions.

Not all the criticisms that have been made of traffic engineering and transport administration above can be applied to the more sophisticated of the 'transportation studies' of recent years: the naive applications of idealized network geometries or the misallocation of resources in a 'bottleneck-fixing' approach are becoming mercifully rarer. A somewhat more imaginative approach is being taken towards the problem of modal balance (see for example Alan Turner on Caracas communal taxis, (43) writing in connection with the studies undertaken by Alan M.

Voorhees and Llewellyn-Davis, Weeks, Forestier-Walker and Bor (10)).

Nevertheless, there seems to be a clear need for a change of emphasis in such studies, which could be promoted in the short run by basic research, academic debate and 'demonstration projects', and in the long run by changes in the regime of research and education (see section 5 below). The issues here seem to be:

(i) A need for more attention to a wide-ranging economic (and social) appraisal of alternative plans, taking full account of the distinctive conditions of a developing country, as discussed in our introductory chapter on the principles of resource allocation.

(ii) Explicit consideration of the distributional and welfare implications of projects, especially how far they meet the needs of 'newcomers' in squatter settlements and their search for employment.

(iii) An attempt to get to grips with the effect of higher levels of road provision on trip-generation rates and land-use; and a consideration of strong policies of restraint and diversion to public transport if these effects seem likely to lead to a large absorption of investment in road schemes with low benefits.

In so far as these developments would increase

the cost and difficulty of transportation studies, there seems to be a strong case for 'paying for' the improvements by a drastic simplification of some of the existing procedures adopted for the basic processes of trip assignment and distribution, speed-flow simulation, traffic restraint and so on. William Alonso has pointed out (19) the limits placed on the validity of very detailed procedures for these processes, by the quality of data available; and this of course applies with special force in the case of virtually all less-developed countries, where the lack of good data is usually a major problem.

2.5. Lower-income cities

2.5.1. Many of the observations above apply with equal force to the low-income cities; for instance, while equilibrium levels of vehicle-ownership and trip-making would no doubt be much lower than in 'higher-income' cities, the provision of transport capacity is usually lower still, so that the volume of 'latent' or 'restrained' demand is very large. An extreme case in point is the central area of Calcutta (17). There are, however, a number of distinctive 'demand-side'

problems which emerge in the low-income cities: three issues in particular seem to call for further research, and are discussed below. They all stem, essentially, from the usually high densities and pronounced 'dual economy' that are, of course, present in virtually all cities in the 'less-developed' world, but which are most pronounced in the large low-income cities.

2.5.2. Levels of income and vehicle ownership are so low for many social groups that most journeys are in some sense 'essential', with the journey-to-work and journey-to-market playing a very large role. Thus while the attainment of high speeds as such may not be very important (see section 3.5 below) the economic significance of achieving reasonable levels of speed and reduction of effort and danger in travel may be very large. Research on this probable non-linear character of the benefits of travel improvements (what is a 'reasonable speed'?) is notably lacking. In particular, large numbers of people walk long distances to work, (see references 7 and 11), or at best travel to work under conditions of acute discomfort and even danger by some inadequate or overloaded public transport facility (17).

2.5.3. An immediate consequence is that a large proportion of road traffic comprises 'slow-traffic': walkers, bicycles, carts and animals. For example, some 30% of trips into Lagos island in 1964 (7) were pedestrians or cyclists, and 22% of 'vehicles' entering the core area of Calcutta in 1967 (17) were 'slow traffic' even before counting pedestrians (19). This creates a very distinctive pattern of traffic demand that cannot be fully analyzed by existing methods*, and which creates special traffic-engineering problems which are discussed in section 3.3.4 below. More crucial still is the need to be able to analyze and predict the 'modal split' of trips between different means of travel--for instance, under what conditions will walkers or cyclists be diverted to public transport? The need for research into this issue has been recognized, and incorporated in a number of current studies (eg. 20), but there is a clear need for further investigation, including fundamental research work.**

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*See (17), p.27, volume-capacity analysis.

**The work should aim at a new theoretical approach, one which recognizes the extremely heterogeneous nature of cities in LDC's.

2.5.4. A third distinctive characteristic of the large low-income cities is the existence of very dense corridors of movement demand which would more than justify fixed-line rapid transit service by the criteria used in industrialized or 'higher-income' cities, and which cannot possibly be met using the existing street system, even with extensive improvement. This situation is emphasized still further by the fact that many major cities (for instance Calcutta, Caracas and Algiers (21) are constrained by their coastal or river-valley sites to strongly linear forms favourable for rapid-transit development. The provision of systems to meet this demand meet with three main types of problems: capital cost, the fact that ground conditions often make underground construction impossible or uneconomic (see 7 and 17), and the fact that the users who most need the system for their journey to work may not be able to pay a fare high enough to cover average cost. Investigation of this latter point, which is clearly crucial in determining how far 'newcomers' can be successfully integrated in the urban economy, seems to be almost invariably weak or absent in studies of such issues.

2.6. Some general findings on 'demand-oriented' planning and transport studies.

A first observation that springs from the reading surveyed above must concern the very large range of standards of analysis that can be found. At one extreme there are many cities where piecemeal 'improvement' solutions are being adopted that are likely to give poor returns. Here, large improvements in practice could be achieved simply by disseminating the existing 'best-practice' transportation modelling (for instance 22, 24, 25) without even raising larger planning issues.

It is by no means the case that the most 'developed' cities have the best planning process. On the contrary: for instance, the major case of a close and explicit integration of land-use and transport planning, with emphasis on catering for 'newcomer' settlements, that appeared in the course of preparing this survey is to be found in the Calcutta "Basic Development Plan" (23). Here a 'two centre' plan, involving a second urban centre at Kalyani-Bansberia has been developed by reference to transport costs and the

optimum use of existing capacity, and the effects of these on new settlement.

It is clear that major improvements in the use of resources in many cities of the less-developed world could be achieved by training, 'professional development' (i.e. retraining) and fellowship programmes designed to produce a 'levelling up' of practice.

There is, however, a need for research to make available improved operational tools to planners in less-developed countries; in each case relevant theoretical research closely related to field studies is required. Four priority areas for 'demand' tudies seem to emerge, and are listed below:

(i) Locational behaviour, especially the choice of residential and workplace location by low income 'newcomers', in relation to the transport system.

(ii) The trip-making and vehicle owning behaviour of households as a function of income, accessibility and other variables--especially accessibility.

(iii) The choice of mode, especially the present and likely future behaviour of those travelling long distances by foot or bicycle.

In addition to this 'behavioural' research, work is also needed on the economic (and sociological) evaluation of the effects of proposed transport systems; and this issue is taken up again in section 4 of this chapter.

3. THE SUPPLY OF TRANSPORT SERVICES AND THE CHOICE OF TECHNOLOGIES

3.1. Innovation

In recent years an awareness of the limitations of traditional ideas of 'technical progress' has gradually gained ground: the growing contact between the engineering and economics disciplines, and development practice, has shown that at any time there is a wide spectrum of possible technical 'solutions' to a problem--with the prospect of an even wider spectrum as a result of suitably directed research--and that the choice of a 'best' solution depends on the prevailing conditions. Probably the most important conditions are the relative scarcities of different resources. Solutions depend also of course on a correct specification of the 'problem', as the preceding sections are intended to show. The approach adopted

in the present section is therefore threefold: (i) to reiterate some of the considerations which should arise in evaluating urban transport proposals for less-developed countries; (ii) to provide a reasonably complete inventory of current technologies and technological research and, (iii) to indicate how a rational process of technology selection and research programming might be achieved.

3.2. Some basic guidelines

The inventory of technologies presented below aims to be rather wider in its scope than any likely spectrum of technologies for a particular city in a less-developed country; but both it and the succeeding section on the 'search' for, and selection of, technologies have been guided by four basic principles.

(i) The policy must make the most intensive possible use of physical capital and transport 'permanent way', especially that already existing.

(ii) Technologies should be sparing in their use of scarce capital, 'modern sector' skills (engineering, management, planning) and intensive in their use of abundant labour, traditional or other labour-intensive

skills and industries, existing raw materials and natural 'permanent way'.

(iii) Technologies should be flexible and capable of incremental improvement.

(iv) The transport sector should be so organized as to meet the needs of social development as discussed in section 4.

These various considerations will, of course, usually be in conflict to a greater or lesser degree; and optimum decision-making then becomes a matter for the planner, administrator and economist (not forgetting the politician), using cost-benefit analysis and other tools discussed in the chapters on resource allocation and policy.

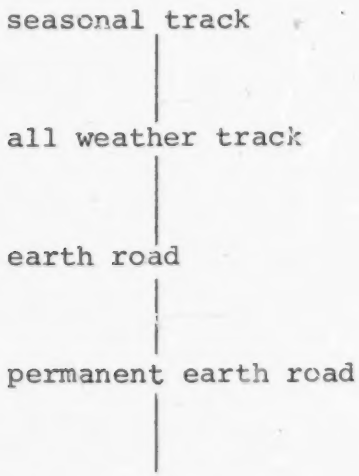
3.3. An inventory of technological research: Road-based systems

3.3.1. Roadway construction

The construction of low-cost roads has been a long-standing preoccupation in 'developing' areas; including 'new' regions in such countries as the US, Canada and Australia. Research in this field received a major impulse from the US

innovations in 'dirt-concrete' beginning in the period immediately pre-World War II; and this is now an active field of research in most developing countries. Systematic listings of this work are available (25). some of its more interesting features include recent work on the use of local or easily available materials ranging from palm kernel shells in Nigeria (26) to rubber latex in Ceylon (27). Similar work is being pursued extensively in the Soviet Union, especially at the 'Soyuzdornii' institute, but is little known outside (28, 29). These are admirable examples of the kind of 'economically oriented' technological research advocated in this report.

Ivory coast research workers (34) have described the following sequence of road types:



and suggested that the maximum traffic acceptable on untreated earth roads is 300 vehicles per day.

The UK Road Research Laboratory, as part of its Tropical Section programme, has published research findings on vehicle operating costs on these different types of road (30). These findings suggest that vehicle operating costs on earth roads can be up to twice as high as on a good bitumen surface, but that operating costs on well-planned and built earth-cement or gravel roads can be as little as 10% more.

It seems clear that there are fairly well-established relationships between the optimal standard of road construction, prices, and the volume of traffic, though current road-research findings, predominantly based on rural conditions, may need some modification for urban use. Unfortunately, such road-research findings have not been systematized in a standard 'design manual', which, like the excellent US 'A.A.S.H.O.' Highway

Capacity Manual (31), can be on every municipal engineer's bookshelf. It is clear that the latter work, though often inappropriate in a low-income situation, is usually there already! A new 'design manual' might call for some new research, but could largely draw on existing work.

This is as true of geometrical design as it is of pavement quality. It is by no means obvious that urban roads should be designed to a 'lower' geometric standard than in the industrialized countries unless this is much cheaper, since low-speed dirt roads often become metalled roads, and in such cases high speeds and poor geometry are major causes of the high accident rates in many of the less-developed countries. But there is clearly a need to think through the possibilities for good low-cost but incrementally improveable layouts. As experience in Karachi has shown, these should avoid large areas of 'reserved' but unused land as these usually attract high-density squatter settlement.

The organization of labour-intensive road construction itself deserves further study and development. As Charles Cockburn points out in his

study of building research in less-developed countries (70), "The building research stations of the world, of which many are in the developing areas, have achieved an impressive output of work in the last twenty years. But it is worth noting how much of this is strictly concerned with technology and design, and how little is concerned with industrial, commercial and administrative procedures for improving construction output". One might add that it is striking how little is often done to maintain and efficiently utilize existing facilities, compared with the enthusiasm for building new capacity. Work is, however, going on on these questions both at the ILO (33) and World Bank (32), as well as in some road-construction agencies (35).

3.3.2. Road motor vehicles

One additional variable which is important in the analysis of the problem discussed above, but which is usually left out of consideration, is the question of variable vehicle design. Since most motor vehicles are built to designs derived from the industrialized countries--or imported directly--it is usually assumed that the type of

vehicle does not need to be discussed. However, a number of variations and options do arise, and these are discussed below.

Even within the limitations set by the present structure of the world automotive industry which is obviously dominated by the needs of the industrialized countries, current research has shown the possibility of design changes which could make possible the use of less-expensive road construction. For instance, a research project in French-speaking West Africa (36) has reported good results from vehicles modified to reduce axle loads, and to operate on large, low pressure tyres (operating at 1.8 Kg/cm^2 or 25 lb per square inch). A number of such small but important innovations were reported at the UN Conference on the application of Science and Technology to Development (UNCSAT), but although the continuing body of this conference (a UN special committee on the application of science and technology) has taken up the idea of vehicle development, there seems to have been little response so far.

It would seem worthwhile, however, to promote

such studies: a useful first stage might be an economic pre-feasibility study to investigate whether the likely benefits of substantial changes in vehicle design* would justify further work.

In addition, there is in existence in many less developed countries a lively 'self-help' industry converting conventional vehicles (especially light vehicles such as motorcycles) for other uses. This industry has not, so far as this reviewer is aware, been the object of systematic study; but in view of its large potential contribution, investigations with a view to stimulating improvements in local vehicle conversion would seem very useful.

3.3.3. Road public transport operation

The operating and cost characteristics of conventional and other bus systems in developing coun-

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* This, like a number of other issues raised by the Infrastructure Project, may depend on the development of viable independent capital goods industries in the less-developed countries--which in turn depends on trade between these countries.

tries have been widely discussed and documented (see for instance 37 and 38); and their potential contribution to the overall transportation system is reasonably well understood. This is not to say, however, that the application of analytical techniques of Operational Research and management sciences generally could not produce better answers to such problems as route structure, tariffs and timetabling. One contributory factor in public transport improvement programmes will certainly be the priorities and special rights of way for buses (bus only lanes, turning privileges, etc.) which have been the subject of intensive traffic engineering study already (40). Traditional, intuitive solutions to bus operating management issues are coming under scrutiny (see 39 and 40) in the industrialized countries and no doubt this ought also to happen in less-developed countries, subject of course to the 'opportunity cost' of the skilled manpower involved being borne in mind. There are also opportunities for simple improvements in vehicles, particularly buses which are generally imported

and often second-hand.*

One issue that does clearly deserve more attention is the question of the collective taxi, known variously as the jitney in the USA, lotacoe in Brazil (14), porpuesto in Venezuela (43) or mutata in Nairobi (44) (where a study of these services is being considered)--and which is virtually universal in the cities of the less-developed world except in those few cases where it is successfully banned by law. Little research has been done on these services; but a study of Hong-Kong, prepared by C.R. Saunders (41) (as part of the research programme of Imperial College, London, on transport in less-developed countries) shows that in the New Territories of Hong Kong communal taxis provided travel in 1967 at a cost of very roughly one US cent per seat-mile, compared with 0.5 cents for buses. More recently, Richard Meier has discussed the process of legalizing such services in Hong Kong (41a).

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* Modifications might include open buses perhaps without windows (in some tropical climates) or the elimination of seats and the provision of grab rails. Vehicles might initially be adapted locally from conventional chassis.

Higher costs per seat-mile seem to be offset by great flexibility and thus much higher average occupancy rates; and this, linked to the low real cost of labour (few jitney drivers appear to receive a formal wage) suggests that such taxis may meet a real need in an economically efficient way, especially if measures for rationalization and regulation were undertaken: the problems of safety and of 'unfair' competition with bus lines that have 'social' obligations would have to be resolved.

To quote a consultant from the Caracas transportation study, 'even with competing lines, lack of co-ordination and no p.r. these cars do a surprisingly good job, and are probably the forerunners of a future transportation system when it is eventually accepted that a small public vehicle can give a more efficient, more widespread service than either large buses or trams, at least in central city areas'.(43) Another writer from the same study quotes a mean taxi occupancy of 3.5 (42).

3.3.4. Other aspects of motor vehicle operation

The distinctive problems of particular motorized road users other than private cars or public service vehicles, over and above the general issues of vehicle and road design are generally well-understood. For instance, it is unlikely that new basic research would be needed on inter-urban truck services or local delivery enterprises. There is, however, one particular issue that arises in the 'dual economy' which should be mentioned. Freight transport provision should include emphasis on services available to small-scale enterprise. One approach to this might be 'postalization', with freight being channelled between local sorting and distribution centres, and with local distribution (perhaps even by hand-trolley or cart or motorcycle-type vehicles) being undertaken by small-scale local enterprise itself. But much small scale freight traffic will (and should) continue to be transported by non-motor vehicles and this traffic is discussed below.

3.3.5. Non-motor travel: Cycles, walkers, carts and animals

The section of this paper describing demand

studies points out the very large role played, especially in lower income cities, by non-motor traffic, and the potential economic importance of the possibilities of travel by different modes available to low income people travelling long distances to work or to market. At what point does a walker become able and willing to travel by bicycle? Under what conditions would he travel by bus? Can the traditional hand cart (much used in Calcutta by small enterprises) be improved and provided for in street design?

Even given that many people continue walking, and given that large numbers of people will travel by bicycle, it is startling to note how little attention has been given to 'traffic engineering' for low-speed road users. This cannot be because of a low potential economic pay-off: quite the contrary. Research in Bengal (45) shows that the effects of sharing of motor carriageways by bullock carts are so detrimental to capacity that 100 bullock carts per hour require about six times as much road space as the same number of cars (i.e. their 'p.c.u.' factor is 6). Heavy carts also often have very harmful effects on the road surface. By contrast, bicycles make very

efficient use of roadspace and cause little wear. Thus it is clear that traffic engineering practices designed to cater for this particular aspect of the 'dual economy' by reducing conflicts between high and low speed traffic and by providing vehicles with suitable road surfaces--perhaps by segregation--could improve the utilization of road investment considerably. There would also be benefits from reduced accidents, which even in a poor country may have high economic costs (quite apart from ethical considerations). As Susumu Kobe says in the Lagos study (46):

> "Much more thought and effort have been devoted to the solution of vehicular traffic problems....Yet more people come into Lagos by foot or on bicycle than are brought in by private cars....More than 50% of the traffic accident fatalities in Lagos are pedestrians or cyclists. This is neither accidental nor inevitable. Traffic lights, safety islands, guard rails at the corners and many other means and regulations must be installed or executed".

While considerable design work, and even basic research for pedestrians and cyclists has gone on in the industrialized countries (see references 47, 48, and 49), and there are numerous examples of segregated pedestrian and bicycle

rights of way, there seems to have been little work on the transfer of these technologies to less-developed countries, where they could be even more useful; nor does there seem to have been a systematic appraisal of the potential economic and social benefit of such a transfer. Research work on the vehicles themselves, presently lacking, could produce considerable benefits.

3.4. Inventory of technological research: Systems with a separate right of way

3.4.1. Road-type systems

The preceding sections have discussed the potential benefits of a piecemeal segregation of various specialized types of traffic (specifically buses and low-speed traffic such as pedestrians, carts, animals and bicycles) from the general-purpose road system. The application of such measures is an example of the type of low-cost incremental solution which is a continuing theme of this report.

In due course, some types of segregated or priority traffic system may come to take on some of

the characteristics of a fixed line rapid transit system in terms of capacity, safety, reliability and freedom from external diseconomies of congestion imposed by other road-users. Three such systems are likely to come under consideration: bicycle and pedestrian ways, (perhaps combined), and segregated busways. Bicycle systems and pedestrian systems have been discussed above; the potential advantages of busways merit further discussion here. They have many of the advantages of 'rapid transit' but at relatively low capital cost; their only major disadvantage is that it may be difficult to provide sufficient capacity by this means on the most heavily-used public transport corridors. And, of course, the system can be implemented 'incrementally', with the same vehicles running on the busway and the ordinary road system, without resorting to the elaborate 'dual-mode' technologies being considered in some industrialized countries (52). Technological research on busways and their engineering performance is already extensive (see references 50, 51, 51a, 51b), but economic research into their performance compared with alternative systems in less-developed countries is still lacking, although there are studies that

indicate clearly how the problem might be tackled (40).

3.4.2. Waterway systems

A very important and often neglected resource is provided by waterways; where already present they provide a free and (usually) self-maintaining 'track' which thus saves both capital and annual costs. As long as high speeds are not required, public and private water transport could have very low costs, utilise existing traditional skills, thus generating development 'linkages', and play (albeit with some health hazards) a multi-resource role in connection with drainage and hydrology. A number of cities (such as Venice and Amsterdam) have enjoyed the benefits of such a system since the Middle Ages; and there seems no reason why, under favourable conditions, the low real cost of labour in developing countries would not justify the cons-ruction of new canals by labour-intensive methods in addition to existing waterways.

While there appears to be little or no theoretical or policy research in this field, there are a

few case-studies in developing countries which have recognized the potential contribution of water transport (though in other cases, opportunities are clearly being missed). The Metropolitan Lagos study cited earlier (7), for instance, advocates the establishment of a water-bus service linking Lagos island to the mainland; similar proposals have been made for Singapore (53).

Since the basic engineering data is readily available in the extensive literature on the technical and cost performance of boats and hydrofoil/hovercraft type of vehicle, there seems to be a very strong case for studies of water transport, including such issues as whether the existence of competing modes, i.e. buses over bridges, necessitates the provision of high speeds. Both general studies--to draw attention to the potential of this technology--and case studies (preferably within the context of metropolitan transportation studies) are needed. There are prototypes for such studies in the work done in Europe on inter-urban water transport (54, 55).

3.4.3. Fixed-line rapid transit systems

The engineering literature covering the design of fixed line rapid transit systems (including such 'new' methods of guidance and traction as monorails and linear induction motors) is well enough known not to need repetition here; and there are numerous excellent analyses of particular problems (see references 50, 56 for example).

In general the new technologies which seem on the verge of practical application at the present time--namely methods of electronic control designed to increase flexibility of service; new forms of propulsion (notably the linear induction motor); and new methods of suspension such as the hovertrain principle, seem likely to have limited application in developing countries since they involve the use of scarce resources (in the first case, skills, and in the last case, energy) in order to achieve high enough speeds and standards of service to enable public modes of transport to compete with the private car--an objective of only secondary importance in most less-developed countries.

The use of the linear induction motor may prove to be an exception, since it maximizes the in-

herent advantage of electric traction for urban use: the economical achievement of very high rates of acceleration, reduced headways and increased line capacity (59).

There are a number of distinctive features of the development of rapid transit service in less-developed countries which are worth emphasizing in the light of the existence of the corridors of heavy and growing mass-transport demand, pointed out in section 2.5.4. and which are accentuated by the strongly linear characteristics of many cities in less-developed countries.

The first is that such systems in developing countries must overcome the initial disadvantage that they make large demands on the most scarce resources: capital and imported capital goods, and foreign exchange, although they may realize some savings in imported fuel once in operation. This, and the lower incomes of users, implies that the 'break-even' daily volume of traffic (reported by many at a 'rule-of-thumb' figure of a flow of 50,000 passengers) may have to be very substantially higher than is necessary in high income cities before the system is economically

viable for the really low-income cities. Such levels of traffic may not be technologically feasible; and unconventional systems may have to be adopted for the very heaviest flows.*

This fact, and the difficulties likely to be created by the difficult underground engineering conditions in delta cities such as Calcutta, Cairo or Saigon, for example, points to the need for alternative solutions.

The most appealing of these lies simply in a more efficient utilization of existing rail capacity. There seem to be numerous opportunities for this, and a number of recent studies have pointed them out.

There seems to be a large potential pay-off from research (or perhaps merely the transfer of existing knowledge) into modification to track, operation and signalling to increase the capacity of existing rail tracks. Work so far in Asia and the USSR (57, 58, 59) as well as in Western railway enterprises suggests that this is the case. The improvement of existing tramway systems--or

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* Some of the latter are discussed in Section 3.4.4.

even the introduction of new ones along similar lines--may also be helpful (13).

An alternative approach would be to try to develop new low-cost modes of mass transport with lower capital costs and simpler, more labour-intensive types of operation drawing less on imported materials and skills. Studies of elevated systems have been put forward to try to meet this need; and a number of research workers (notably Richard Meier, 60 and 61) have suggested simplified rubber-wheeled transit systems running on cement or wood tracks and achieving high acceleration but low top speed--optimal characteristics in dense low-income urban areas where the 'value of time' for evaluation and modal choice is not very high. This type of technology would lend itself to the design of the type of lightweight, environmentally acceptable elevated structures which have been proposed as an alternative to costly and difficult underground works (see 18, p. 137); and might lend itself to incremental improvement beginning with segregated busways and culminating with the use of linear induction motors. This type of 'scenario', however, would need much more research of a kind

oriented toward phased implementation and not currently available. Such systems could be best designed in conjunction with a strong land-use policy, which they would themselves be a main instrument for achieving.

3.4.4. Short-distance, high-density modes and other innovations

As was pointed out in the preceding section, there may be cases of very heavy, relatively short distance (less than 2 miles), demands for passenger movement: a good example is the East-West route in Central Calcutta (18 p. 129). The need for high speeds on such routes is not critical, and the operation of rail systems not only presents operational difficulties but may be unable to provide sufficient capacity. In such cases--which will notably arise when journey to work flows converge at a central area (typically at a railway station or bus terminal) it may be feasible to use the type of passenger conveyor or 'integrator' systems currently being developed for use in dense urban areas in the industrial countries (62, 63), with sufficient benefits in reduced street con-

gestion to justify the costs.

Other 'sophisticated' modes of city centre transport (such as 'cartrack' and 'guideway' systems) or for transport in residential areas (e.g. 'dial-a-bus') (64, 65) seem unlikely to be helpful in less-developed countries, since they are highly capital-intensive--usually designed with automation of control as a major consideration--and intended to compete with the flexible service provided by private transport at high levels of car ownership. However, it is worth pointing out that the existing 'communal taxi' system, regulated and upgraded in the way suggested in section 3.3.3., would to some extent play the same role and enjoy some of the same advantages--especially if some way were found of admitting them on a toll basis to at least some sections of segregated right-of-way.

3.5. Criteria for choosing techniques: towards a systematic technology-search and priorities for research

On the basis of the kind of 'inventory' sketched above, we can begin to see how a detailed research

programme might undertake a systematic 'search' of available transport technologies on the basis of national economic criteria.

It is, unfortunately, striking how rarely such appraisals have been undertaken in the urban transport sphere, when one considers that they are routine in the aerospace industry when market research for new vehicle types (eg. 'air-buses' or hovercraft) is undertaken. Even the generally admirable work of the Carnegie-Mellon University Transportation Research Institute on new technologies referred to above (64) does not include in its published records on Advanced Urban Transport Systems any systematic discussion of the relations between transport demand, cost and value of time for trips of varying length, which could serve to measure the 'market' (either directly or in terms of social benefits marketable to a public agency) for each potential system. Some work of this kind has been undertaken by Lesley (66) and by G. Bouladon of the Battelle Institute in Geneva (62). The latter has led to the identification of a 'transport gap' for large volume short trips in city centers, and the development of the 'integrator' system dis-

cussed in section 3.4.4.

There is a clear need for similar studies using the appropriate parameters for a 'less-developed country' situation, if effort on technological innovation is not to be misdirected. Certain parameters will merit particularly detailed attention. Notable among these is the value of time attributed to travellers, which will determine how much emphasis is placed on the speed of travel and how high a return is expected from increasing it. Some studies of the behaviour of present vehicle-users (67) have suggested values of time almost as high as are found in Europe; but to use these measures to represent 'resource costs' may over-rate the value of time and lead to a mis-allocation of resources (68). Almost equally important is the need to value resource at opportunity cost, taking account of shadow pricing and discounting as discussed in section 4.4., and giving a correct treatment of market prices and tax 'claw-back' (69).

The necessary techniques for such studies are available, and it is clear that an overall technology review should both precede and accompany

the process of technological research into the various issues and potentialities described in the inventory given above.

4. PRICING, REGULATION, ADMINISTRATION AND MANAGEMENT

4.1. As is pointed out in a number of references above--notably that by Charles Cockburn in his studies of the building industry (70)--the identification of improved 'solutions' (by better knowledge both of demand and of technology and supply conditions) as a result of research does not in itself guarantee a successful outcome for attempts to improve transport (or another activity) and its contribution to development in an urban context. Equally important are the measures and policies involved in the implementation of the 'solutions' decided upon: indeed, a wise choice of 'solution' will take into account that the capacity for practical policy-making and management is itself a scarce resource. The following sections accordingly discuss research into both implementation and management.

4.2. Management

Some detailed management issues both in the field of roads and other public rights of way (where traffic management, traffic, law enforcement, driving and vehicle standards, etc., are important in determining the standard of performance achieved with existing roadspace) have been discussed in section 3, together with a number of the operational problems and opportunities facing public transport operators.

There is undoubtedly scope for improvement in many other management functions of those responsible for urban transport, but most of these issues fall outside the scope of the present study. One particular category of problems concerns the efficient administration of labour-intensive methods in large organizations (notably railways or city public utilities). Since such enterprises are often deliberately overmanned in order to reduce the impact of urban unemployment, it is often difficult to measure and achieve efficient use of labour.

4.3. Pricing and Regulation

4.3.1. A great deal of work has been done on the pricing of inter-urban transport facilities: optimal rate structures for railway systems, the possibility of toll roads, and so on. The need for more rational pricing policies both to achieve better utilization of existing capital assets, and to help guide new investment in an optimal direction, has been recognized in studies in a wide range of countries (71, 72) and in the project appraisal work and research of the World Bank (73, 74). A typical issue has been the problem of the distortion of resource allocation between road and rail modes of transport as a result of the provision of 'free' road-space to carriers; it is interesting to note also the emphasis placed by the last reference on the importance of the foreign exchange costs of transport (see 4.4.2.)

4.3.2. Moreover, the transfer of this type of work to the urban context, while under active consideration in conjunction with the issue of pricing against congestion in the industrial countries, does not seem to have been very seriously considered in less-developed countries. Since 'road pricing' is generally thought of in asso-

ciation with complex electronic metering systems, etc., this is not surprising. But in fact, simple means of pricing (by means of entry permits for central areas, for instance) may be available to price the privilege of private cars driving on publicly financed (and also congested) urban roads. This is a notable research need that does not seem to have been followed up yet, though at least one tentative initiative in this direction is known to the present writer. Such work should also cover the application of marginal cost pricing to public transport.*

4.3.3. In general, the whole issue of road and parking charges, public transport fares and regulation policies should be given detailed attention in urban transportation studies, with a view to making the fullest use of existing transport capacity. Experience in industrialized cities suggests that such an approach including low-cost

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* A good example here might be a decision to run urban transport services on existing inter-urban rail tracks. If part of the cost of these tracks were to be allocated to the urban services, they might make an 'accounting loss' at prices users could pay. But if services were correctly priced at the marginal cost of the extra trains, the service might well be 'paying its way' economically.

traffic engineering measures like turning restrictions, can often stave off the need for major works for some time, thus saving valuable capital.

4.4. Investment appraisal

4.4.1. This latter point leads us directly to issues which arise in the appraisal of transport projects. Some of these--such as the 'value-of-time' problem--have already been raised in connection with the argument of section 3, for the systematic review and appraisal of alternative technologies.

At this stage in the argument, we can draw together the discussion of technology-appraisal with the overall principles of resource allocation discussed elsewhere in this report.

The crucial stages of project appraisal from the point of view of getting transport decisions right seem to be three:

4.4.2. The estimation of capital costs and 'resource-costs' of operation.

Some discussion of this is given above in section 3.5., but the importance of attributing correct prices to resources, including shadow prices in the case of goods like unskilled labour, or imports, whose abundance or scarcity is not fully reflected by market prices, is so great to be worth restating. A classic example of an investment decision which may well have been, at least for a time, wasteful is the decision of the British Railways Board in the late 1950s and early 1960s to convert from steam to diesel traction. Since sterling was substantially overvalued at a time of serious balance-of-payments difficulties, and thus the price of imported fuel was less than its true long term cost, the apparently 'profitable' decision to convert was probably taken substantially too soon, and resulted in a substantially poorer economic performance than could have been achieved. Similar situations are even more likely to occur in urban situations in less-developed countries, where resource constraints are often much more acute.* The necessary re-

*In reference 74, it is pointed out that capital investment for transport accounted for 15-30% of all capital investment and about 40% of foreign exchange use (50% in Ecuador, 60% in Syria) in a 'typical' less developed country in the early 1960s.

search on these issues exists, and simply needs to be applied in practical decision-making.

4.4.3. The estimation of annual project costs and benefits.

Operating costs of vehicles and simple methods of appraising benefits from transport improvements in terms of savings in these costs and in journey time are usually well known to practicing highway and other engineers, and to government departments. However, such methods call for comment and sometimes for re-examination in four crucial areas:

(i) Where a complex transport network is concerned improvements in economic efficiency do not necessarily correspond automatically to reductions in the total costs of trip-making, as mean trip lengths may increase in response to improved opportunities. Methods for dealing with this point have been extensively studied and are available for use in metropolitan transportation studies (68, 75)

(ii) Results are usually very sensitive to assumptions about the value of time. These are usually derived from behavioural studies but the results of such research in less-developed countries (for instance into drivers' choices between ferries and toll bridges) may need further discussion and research. For instance, a study

in Kenya by the UK Road Research Laboratory (67), seems to show values of time not very much lower than in the UK - in spite of the fact that incomes (even among car owners) are much lower. This paradoxical result may perhaps reflect a culturally-induced impatience with delay, preference for high speeds, and thus willingness to pay to save time, which does not really reflect the potential 'earning power' of the time saved. In the jargon, the 'behavioural cost' exceeds the 'resource cost' of time (68).

Since we do not presumably want to make major errors by over-valuing time-saving improvements, and thus over-spend on them, this is an important area of research in transport economics that would reward further study.

(iii) A controversial though somewhat less crucial issue is the correct treatment of changes in tax revenue as a result of projects. An agreed treatment of this problem now seems to be emerging (69) but a natural component of the studies referred to above would be a reconsideration of the issue in a 'development' situation.

(iv) Much more consideration is needed of what are often dismissed as the "impact" effects of transport investment: the wider social and economic consequences. In particular, we need to estimate the effects of providing low-income people and small-scale business with cheap and to some extent quick journeys; and the indirect effect of transport investment is, for example, stimulating local enterprises by generating demand for their product, and thus creating employment and on-the-job education for nationals--what economic historians call "Backward-and forward linkages".

4.4.4. The combination of capital costs, annual costs and annual benefits by discounting.

Project appraisals are still commonly carried out for a single future 'design year'. But to take an obvious example (which could easily be adopted by analogy to such other fields as those of water or energy) it will not be good enough to build a road now in the expectation that rapidly rising demand in 1980-1985 will give it a good rate of return in 1982--a type of statement one can often see in planning documents from the industrial countries. Each future year must be considered--the nearer the more important--and the simple and well known technique of 'discounted cash flow' should be used to achieve this. No research is needed--but, as in many other issues in this paper, suitable measures to encourage the application by decision-makers of well-known methods.

5. SUMMARY AND CONCLUSIONS

5.1. The general direction taken by the findings of this review may be summed up briefly as follows. While there are undoubtedly certain opportunities for 'invention'--the introduction of radi-

cally new technological solutions--these are less likely to be available in a relevant and useful form for the transport sector in less developed countries than for certain other activities (like sewerage, with new small-scale bio-chemical processes) or for transport in industrial countries. In the latter case, new labour-saving methods based on cybernetics and automation are economically attractive, and very high standards of performance are needed.

It seems more likely that major steps forward in improving transportation service in less-developed countries will come less from 'invention'--though there are opportunities for this--than from 'innovation'--the adaptation of existing technologies and 'know-how' in new forms and combinations better adapted to the needs of low-income cities.

5.2. One partial exception to this may lie in the 'soft-ware' of planning for transportation demand and supply on the city scale. There is both extensive scope and need for improvements on the basis of a comprehensive 'systems approach' to the models used for transportation planning in

the context of the changing land-use pattern of the city, as well as for the dissemination of current 'best practice' in the preparation and appraisal of transport schemes. There is a strong case for paying for such improvements by simplifying the transportation planning process in those frequent cases where planners (often consultants from the industrial countries) use methods whose complexity and sophistication is not justified by the quality of data available.

At the same time, there is an urgent need to focus attention on important transportation issues characteristic of less-developed countries: slow-moving traffic, the walk to work, and the choice of mode at very low incomes.

To achieve these changes of emphasis, there is a need both for fundamental research coupled with model development and testing in particular locations, and for a process of dissemination (by programmes of education, 'professional development' or retraining in mid-career, and publication).

5.3. On the technological 'hardware' or 'supply' side

of the problem, the emphasis is strongly on 'innovation' aimed at economizing on the use of scarce resources, and making the fuller use of existing infrastructure.

In certain areas of work--notably road construction--there are already extensive research programmes; but there are other areas where technological research clearly needs to be intensified. Areas of research need have been identified as follows:

(i) Radical road vehicle re-design and the re-design of 'road plus vehicle' system

(ii) Waterways and water vehicles

(iii) Flexible geometrical design of roads and low-cost traffic control with special regard to slow traffic and pedestrians (including improvements to 'slow-traffic' wheeled vehicles)

(iv) Study of road-like rapid transit systems capable of incremental introduction.

In addition to technological research proper, two other activities are called for: the dissemination of findings in a usable form to such practical decision makers as city engineers; (the preparation of a new city transport design manual

is proposed); and the carrying out of a systematic and detailed 'technology-appraisal' study, sieving current and proposed hardware systems according to criteria of economic and social performance and practical implementation possibilities.

5.4. The effectiveness of the measures suggested above will depend very critically on the managerial capabilities and policies of implementation (including legal regulation and pricing policies) which are available; and here again the establishment of training programmes as well as large 'implementation' components in major studies (not 'pilot-projects') could have the effect of raising the average standard of practice in a very useful way.

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E. URBAN LAND

1. There are three fundamental issues in any discussion of the technology of making land usable:

(i) The technology of making land usable is highly developed and readily available. There are existing techniques for converting swamps, tidal land, low-lying property and steep slopes into habitable land.*

(ii) The techniques of changing the use of the land, without altering the typology, also exist. These are slow labour intensive operations and often incremental.**

(iii) Location of land greatly determines its usefulness. Except in extreme situations, the problems of laying foundations in city centres are almost irrelevant. The value of the land in central areas is great enough in terms of economic and social value, so as to discount any but the most elaborate problems of construction.

1.2. Moving from the predominantly technical problems of land itself, there are three ways of increas-

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* An excellent example is the work of the International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

** Such as the result of stilt and catwalk squatter towns in Guayaquil or the Favelas and Barrios on the steep and precarious hill slopes of Rio de Janeiro and Caracas.

ing urban space. The developer, whether public or private, can:

(i) build upwards;

(ii) reclaim hitherto unused land near the city centre; (including 'floating platforms' and colonies of boats);*

(iii) convert peripheral agricultural land, forests or waste-lands into suburban housing estates or satellite towns.

1.2.1. The clearance of squatters does not in any way extend the urban space. No net gain of space--or even land--is represented by the shifting of groups of populations from one place to another. This is obviously the case as, even if not officially rehoused, squatters must rehouse themselves.

1.3. Assuming that the developer pays the actual full cost--which is a rare event--the decision as to which of the three solutions is implemented depends upon the relative costs of:

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* Such as the boat colonies of Dacca or the sampang settlements at Aberdeen, Hong Kong.

(i) Land acquisition;

(ii) reclamation, including drainage and levelling;

(iii) foundations and construction of housing and other building;

(iv) roads and infrastructure services;

(v) transportation;

1.4. When these five cost elements are applied to the three options open to developers of urban areas, the general description of each option is as below:

1.4.1. In building upward (the Manhattan solution), the high costs of land acquisition, of foundations and of construction are offset by the low costs for modifications in urban infrastructure. Land reclamation and transportation cost virtually nothing.

1.4.2. The reclamation of unused central land (Singapore, Victoria Island Lagos) naturally involves high costs of reclamation and of foundations and construction. Infrastructure incurs moderate costs, as does transportation while there are almost no acquisition costs.

1.4.3. The option chosen by growing inland cities, converting peripheral land, results in heavy costs for extension of the infrastructure network and high costs of transportation, including roads. Land acquisition costs and construction costs are comparatively low. There are no reclamation costs.

1.5. The cost elements and options for developing urban land can be put together into an interesting matrix.

	Building Upwards	Reclamation of Urban Land	Use of Peripheral agricultural or waste land
Land acquisition	£££££	£	£
Land reclamation, levelling and drainage	0	£££££	0
Roads and urban Infrastructure	£	££	£££££
Transportation	0	£	£££££
Foundations and construction costs of housing and other buildings	£££££	£££££	£*

* The cost of housing on peripheral land is shown as low, because housing on such land can be produced by self-help methods.

1.5.1. The value--or benefit--of the land gained through the use of any of these systems of alteration depends on both the 'conversion' costs of the land and on its potential use. The potential use of the land is a function of the distance from the city centre and other market forces. In urban areas the market forces are many times greater than the conversion costs in determining the 'benefit' of increasing the available space.

1.5.2. The comparative analysis of alternative ways of extending urban space has been formalized through the application of 'Threshold Analysis' (developed by Malicz, Koslowski and others in Poland). Threshold analysis is now generally part of the curricula of planning schools throughout the world, and is even sometimes used in urban policy decision-making. The method, through research, study and use, is undergoing steady and progressive refinement.

1.6. There are many examples of how technical advances have affected the comparative weighting of the five cost factors.

These examples include:

(i) Upwards solutions have become more competitive through developments in steel and concrete constructions pile foundations, and elevator design.

(ii) Progress in earth-moving and dredging technology has sometimes tipped the balance in favour of reclamation.

(iii) Advances in transportation systems and techniques have assisted the development of peripheral extensions.

1.7. Research into these facets of the urban land problem finds great rewards in normal commerce. The need for special, funded investigations into these technical and economic areas is not of great urgency.

1.7.1. However, the complicated and unique social problems of rapidly growing cities in LDC's do require further study. Newcomers to the city require some form of shelter. The implications of this need on the behaviour of the newcomers and the land use policies of the cities are the most obvious examples.

This can best be explained by stating the common dilemma:

-- a newcomer to an urban area can only gain a

foothold in urban life by residence in the centre city;

-- being without financial resources the only land left to the newcomer is handicapped land, that is, illegal or unreclaimed 'useless' land;

-- if he reclaims such land, pressure will grow to force him out of it;

-- if the authorities reclaim the land for newcomers, pressures will force this land to be used for more immediately productive purposes.

In this problem of providing a 'reception area' for newcomers, the main thesis of this report finds perhaps its most obvious example: the 'technology' of providing the required land, shelter and services is known but the attitudes and adpatation of the necessary techniques is sorely lacking.

1.8. Another consideration of quite fundamental importance has only just begun to enter the thinking of urban planners and administrators. It is the ecological effect of land reclamation and land use.

1.8.1. Ecological effects can be both negative and

positive. By far the best known example for the negative effects of large human settlements on their environment is the deforestation of the hinterland of all our older cities with its obviously harmful results for fauna and climate. An equally well known positive example is the improvement of the urban climate through intensive tree planting and gardening (e.g. in New Delhi).

1.8.2. It is unfortunately easier to expand the list of negative examples--not because planners and urban administrators "don't care"--but because of a regrettable lack of communication between the biological sciences and those who have to make decisions in fast growing cities.

CHAPTER IV: SUMMARY OF CONCLUSIONS AND RESEARCH NEEDS

1. Summary of conclusions

1.1. One fundamental principle is maintained throughout this report: that the present 'best practice' in the development of urban infrastructure systems is described with indications of how it could be used in the most cost-effective manner.

1.2. The findings of this report indicate that there are four distinct ways in which the performance of urban infrastructure systems in less-developed countries can be improved. The four approaches involve the application of engineering skills but only one is a matter of 'technological breakthrough'. All, however, imply radical changes of attitude to urban infrastructure systems, both in the 'software' of management and planning, and in the 'hardware' or physical equipment.

1.3. <u>Four approaches to the improvement of performance</u>

i. Improved utilization of existing infrastructure.

At present, under-utilized capacity

frequently exists (often unrecognized) along with the inadequate provision of the service concerned. This can be the result of poor administrative co-ordination; or a failure to imaginatively recognize opportunities. For example, many cities with acute traffic problems could make fuller use of their waterways; or adapt their urban main-line railways to carry local traffic. The long-term solution in such cases lies in the fields of planning, management and public administration. A combination of immediate steps to improve planning practice and long-term measures to improve education and training can lead to 'better' if not 'best practice'.

The same can be said of a more subtle but extensive form of under-utilization of resources; the under-utilization which results from inefficient pricing and regulation of infrastructure services. While there is a need for further research on this point, it seems clear that (for example) the pricing policies adopted for water and electricity often encourage wasteful consumption by some users, while denying others the opportunity of making economically efficient use of the same resources.

ii. Improved choice of technique.

In designing an urban infrastructure system, the designer is faced (whether he is aware of this or not) with a choice from a wide range of alternative technologies--all have different cost characteristics, different requirements for energy, labour and skills, and varying imported resources components. Under these circumstances, the 'choice of technique' becomes a question of engineering economics in the broad sense, the wider social and economic concerns (the educational effects of a project; its effect on the balance of payments), and strictly financial criteria.

In each of the five surveys which form the main part of this report, there is evidence that in the future technological decision-making could be improved. For example, less capital-intensive methods of sewage treatment might be adopted. Public transport systems such as busways, (which can be 'phased' or constructed in stages while forming at each stage a complete, efficiently operating system) may, under appropriate conditions be preferred to a fixed-line rapid-transit system which does not have this characteristic. The application of discounted cash-flow (DCF) methods of project appraisal--in order to determine the phasing--is likely to put in sharp relief the heavier load placed on the available resources by the 'lumpier' investment.

iii. Innovation

It is important to distinguish between innovation and invention. Innovation involves the practical use of reasonably reliable techniques which have not been widely applied, while invention is the creation of new techniques. Even without invention, there are a queue of feasible technologies available to the innovator. Numerous examples of innovation are given in earlier chapters of this report (the introduction of simple water-metering devices; bus priorities and privileges in traffic management schemes, etc.).

iv. Invention

While much can be achieved without the introduction of completely new technologies, there are a number of aspects of urban infrastructure planning where major technical improvements would make it possible to solve severe policy problems. For example, improved biochemical knowledge may make it possible to provide efficient and comprehensive

> sewage disposal in poor cities. And, of course, there is a very general need for appropriate technological invention--that is, those which really do prove, on the basis of a realistic economic assessment, to cut costs or improve performance in a cost-effective way. Novel methods of road construction provide an example of the former; the latter may in some cases be typified by the introduction of the linear induction motor for rapid-transit systems.

1.4. In each of the ares of policy described above, there is scope for new initiatives and programmes designed to improve the performance of urban infrastructure systems. These opportunities include: (a) scientific and technological research as indicated in this report, and the development and implementation of new technologies; (b) research and implementation work on the economic and social implications of urban infrastructure policy, and especially on the management and engineering economics of the choice of technology; (c) management and pricing and regulation of the use of existing systems. The subsequent parts of this chapter describe a number of these opportunities for action in more specific cases and examples.

2. THE RESEARCH

The research to be done can be roughly broken down into five types of research or fact-finding. The most important of these is the work noted in 2.1 below, emphasizing 'process' and 'system'.

2.1. Research into the correlation of infrastructure systems and sub-systems and their economic consequences with the process of urban settlement.

Much work has been done on the individual elements within the urban infrastructure while little attention has been paid to the relationships between the various elements. For example, the allocation of large amounts of capital in one area saves expenditure in others. If transportation is effective, extensive savings can be made in the costs of land, drains, waste disposal and water. Further such a dispersal into semi-rural conditions can allow newcomers a transition period to fully urban conditions.

If the entire urban infrastructure were to be considered as a single system, with the elements as sub-systems, attention would be clearly focused on the interaction of the elements, their relationships to each other and the often un-

observed social repercussions of infrastructure decisions. Such an approach might also more clearly place the process of urban settlement in the context of the existing city.*

Several suggestions for further study mentioned in this review indicate the value of this systems approach even when looking at one element in detail. These include:

(i) Integration of on-going research on collection, transportation etc. of wastes into a complete sanitary service.

(ii) How present policies on electricity tariffs are arrived at and what social and political considerations effect them.

(iii) Explicit consideration of the distributional and welfare implications of projects--especially how far they meet the needs of newcomers in squatter settlements and their search for employment.

(iv) Locational behaviour--especially as related to choice of residential and work place location by low income "newcomers", as related to the transport system.

(v) Trip-making and vehicle owning behaviour of households as a function of income, accessibility and other variables, especially accessibility.

(vi) Wider social and economic consequences of transport investment.

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*See John Turner, particularly the American Institute of Planners Journal for November, 1968.

2.2. Problems where the basic technology or technique is well-known but further work is necessary on its applicability to the particular economic, climatic and social conditions in the LDC under consideration:

(i) Cost data of surface water pipe supply systems.

(ii) For power supply the application of a theoretical framework to:

improve pricing structure

treat uncertainty

establish the real cost of capital and foreign exchange and other inputs.

(iii) Attention to a wide-ranging economic (and social) appraisal of alternative transport plans, taking full account of the distinctive conditions of a developing country.

(iv) Improvements by drastic simplification of some of the existing procedures adopted in transport planning for the basic processes of trip assignments and distribution, speed-flow simulation, traffic restraint, etc.

(v) Non-linear character of the benefits of travel improvements (e.g. economic significance of achieving reasonable levels of speed and reduction of effort and danger in travel).

(vi) Organization of labour intensive road construction.

(vii) Economic research into the performance of busways compared with alternatives in less developed countries.

(viii) A systematic and detailed transportation "technology appraisal" study, sieving current and proposed hardware systems according to criteria of economic and social performance and practical implementation possibilities training programmes.

(ix) The economies of water or wind-driven generators, solar power and organic wastes in the provision of domestic power supply.

2.3. Situations where information is required on which to base infrastructure decisions (and the methods for collecting this information are known).

(i) The quantitative relationship between the provision of water and the increase of health standards (including the effects on health of marginal increments to the supply of water and the effects on health of different methods of supply provision).

(ii) The relationship between tourism and water.

(iii) The quantification of medical expense savings arising from improved water supply and the increased output per worker and longer life span.

(iv) Anticipated demands for water as incomes rise.

(v) Effects of water pricing systems (metering, limiting valves and fixed payment, etc.) on demand.

(vi) Use of communal collecting points for refuse.

(vii) True economic costs of vacuum tankers for the transportation of liquid faecal

matter (an incremental system) v/v the pipe line system.

(viii) Consumer attitudes toward interruption and variability and electricl appliances.

(ix) The effect of social traditions on the land market and on land values.

(x) The effects of different traditions of land tenure on the availability of land for public purposes and housing.

(xi) The ecological effects of various methods of land reclamation, such as drainage of swamps, securing of tidal lands, clearing of forest or bush, denuding of slopes, reducing rainwater absorbent surfaces in cities etc.

(xii) Self-help methods in land reclamation.

(xiii) Effective land use control in LDCs.

(xiv) The effect of plural economies on the competition for urban land.

(xv) Investigation of all aspects of the collective taxi.

(xvi) Consideration of small scale enterprise in freight transport provision.

(xvii) Value of travel time.

(xviii) Investigation of fare levels for journeys to work which the newcomer can afford.

(xix) The choice of mode of travel, especially the present and likely future behaviour of those travelling long distances by foot or bicycle.

(xx) The effect of higher levels of road provision on trip generation rates and land-use and a consideration of strong policies of restraint and diversion to public transport if these effects seem likely to lead to a large absorption of

investment in road schemes with low benefits.

2.4. Areas where there is some hope of a technical breakthrough.

(i) Protein production from algae.

(ii) Applied research and finances of resource recovery oxidation ponds (photosynthesis).

(iii) Resource recycling based on economic application of NASA work.

2.5. Areas needful of minor but important technical improvements.

(i) Rainwater collection schemes as a temporary contribution to urban water supply.

(ii) Consideration of small groups of urban dwellers as "villages" and the applicability or rural water provision and waste disposed techniques, rainwater collection, ground water schemes.

(iii) Testing and standardization or new materials for water provision.

(iv) Desalination to extend already developed conventional water systems.

(v) Mass production of well-designed latrines making use of impervious synthetic materials or in the design of wet latrines, with soiled water used for flushing.

(vi) Composting: The use of earth moving equipment.

(vii) Production of methane gas and waste disposal systems.

(viii) Design of electrical appliances to operate over greater ranges of voltage and frequency (in the short term).

(ix) Radical road vehicle re-design, and re-design of the "road plus vehicle" system.

(x) The design and use of waterways and water vehicles.

(xi) Flexible geometrical design of roads and low cost traffic control with special regard to slow traffic and pedestrians.

(xii) Study of road-like rapid transit systems capable of incremental introduction.

(xiii) Studies of modifications of existing rail track systems--track operations and signalling to make their use for commuter transport possible.

3. RESOURCE ALLOCATION

3.1. It is not possible to consider the choice of technologies and policies for particular aspects of a city's infrastructure in isolation from the decisions which have to be made regarding other aspects. We are faced with a problem of allocating scarce resources (notably capital, skilled labour and imported goods and services) both between competing activities now and at different times in the future. In spite of the large

practical and administrative difficulties, there is a very pressing need for improvement in the clarity and efficiency of decision-making about resource allocation.

Should we invest in water pipelines or water tankers--or in dual purpose vehicles that also serve for the journey to work? Should we invest in lorries now, replacing them over a specified period of time with a fixed distribution system for water and a formal bus system for transport?

3.2. In order to deal with such questions, we need both a series of tools of management and project (or policy) appraisal; and also a general managerial framework in which to apply these tools. The individual methods of management and project appraisal are conceptually, very simple. They need not necessarily be "sophisticated management methods" that will automatically put a strain on the available manpower of city authorities; rather they are a means of organizing such information as is available in such a way as to facilitate rational decision-making and the efficient uses of resources. Since government bodies in developing countries are often not

lacking in clerical staff (as distinct from staff with executive skills), the necessary information-processing work need not be a major burden.

3.3. While such methods can be used in isolation for project appraisal and similar purposes, they have their main usefulness when there is an organized framework for overall decision-making. Such a framework may take many forms: some current ideas and practices have come to be grouped under the heading of "programme budgeting" or PPBS (planning-programming-budgeting system); but useful improvement in the clarity of decision-making can be achieved without resorting to the complex data-processing systems which have sometimes been associated with this title.

3.3.1. A programme budgeting framework for a city government would consist essentially of the following procedures:

(i) identify the types of activity or services the city wishes to provide.

(ii) establish general goals for each of these programmes.

(iii) set up procedures for measuring the 'output of each programme in terms of its achievement of these goals, bearing

in mind the technical relationships between the performance of each system and the links between them (eg. transport, land costs for settlement; water and drainage).

(iv) set-up procedure for measuring the real "opportunity cost", in terms of foregone alternatives, of each programme (this is not necessarily the same as the accounting cost*).

(v) appraise 'output' compared with cost for each programme proposal for a number of future years.

(vi) work out "trade-off" preferences between alternative programme outputs over a series of years.

(vii) adjust programme proposals to achieve a 'best' result according to the criteria above.

3.4. Of course, the information in use (apart from the severe problems of completeness and accuracy) will be very heterogeneous in character, and full weight must be given to social considerations (for instance the social value attached to the spreading of health standards, independently of the direct economic benefits) which may not be

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* A good example here might be a decision to run urban transport services over existing inter-urban rail tracks. If part of the cost of these tracks were to be allocated to the urban services, they might make an "accounting loss" at prices users could pay: but on the correct economic criterion of marginal cost, the service would be paying its way (e.g. paragraph 4.3.2. of Section D).

fully quantifiable. For these reasons, no decision-making system can be more than an aid to the clear organization of information for the making of difficult and often very crucial decisions.

CHAPTER V THE NEXT STEP....

1. The suggestions for further research outlined in the preceding chapter cover a wide spectrum of subject areas, demanding of a variety of specialists. There are two possible methods of stimulating such research:

1.1. the support of specific projects to be carried out where the relevant manpower is established and compatible research is on-going;

1.2. the founding of new multi-disciplinary centres for the general and specific study of urban infrastructure in LDC's.

2. Some of the arguments in favour of the first suggestions, the dispersal theory, are:

(i) In supporting a variety of applied research programmes, a diversity of approach is assured and the emergence of a single, possibly dogmatic 'school of thought' is held in check.

(ii) Research programmes can be built upon existing experience.

(iii) Established teams with their own (productive) working methods can be maintained.

(iv) The overall work of urban infrastructure problems in LDC's will not have a specific regional or national identification.

(v) Money given to 'top up' on-going work or to bring a specific project into the research programme is often better value than supporting a new organization.

(vi) It is more economical to strengthen an existing institution than to create an entirely new structure.

(vii) The research work can be of benefit to the various institutions by allowing the findings to filter into teaching programmes, publications, staff seminars, etc.

(viii) If institutions are carefully chosen, the research work will profit from the established status of such institutions.

3. New centres for research on the problem of infrastructure in LDC's also have certain advantages. These include:

(i) A single aim or goal is clearly identifiable and recognized within and without these centres.

(ii) Competition of other research subjects is minimized within the institutions.

(iii) New organizations have greater potential to avoid biases and ideological and methodological prejudices.

(iv) The results of the research avoid the identification (and possible stigma) with particular established institutions.

(v) Coordination and communications between projects is simplified by physical proximity.

(vi) The chance of duplication and overlapping of research effort is minimized.

(vii) Multi-national staffing, thus tapping international sources, is facilitated if the centres are clearly set up as international.

(viii) Authority and prestige will evolve based on being one of the centres which consider these infrastructure problems.

4. The above pros and cons indicate that the real problem is not institutional. Also that there a are few areas where technological break-throughs can be anticipated. The really vital considerations are:

(i) That the research suggested in Chapter IV must be carried out, and by those most capable of doing it;

(ii) That the links between the various elements of urban infrastructure must be clearly defined and research into these links should come before technical research;

(iii) That attitude is as important as expertise or professional competence

(iv) That attitude, particularly to the relationships between the elements of the infrastructure, is necessary in applying the technology, in asking the right questions of the available technology and in working in teams within the known constraints;

(v) Above all, the results of the research suggested above, must be communicated to those in the field in a way they can use.

4.1. This last point can not be emphasized too strongly. No matter how useful the findings of any inquiry may be, they are of no practical significance and will remain 'theory' unless such findings enter the normal orbit of a harassed urban administrator in Malaysia, Malawi and Mexico.